SOUTH OF SCOTLAND ELECTRICITY BOARD

FAULT INCIDENT AT

YOKER FERRY ROAD 132/11 kV SUBSTATION

ON 4TH MARCH 1980

REPORT OF THE PANEL OF INQUIRY

APPOINTED BY

THE CHIEF ENGINEER, TRANSMISSION/DISTRIBUTION

South of Scotland Electricity Board
Memo

To: As undernoted

From: Chief Engineer Transmission/Distribution

Your Ref:

Our Ref: RMG

Date: 7 July 1980

SCM	D.C.M.	FC	LC	CD	SGE	AA

10 JUL 1980

Subject: FAULT INCIDENT AT YOKER FERRY ROAD ON 4 MARCH 1980
REPORT OF PANEL OF INQUIRY

As you are aware I set up a Panel of Inquiry to investigate the above incident and to make recommendations.

I have received and accepted the Panel's Report which the Director of Engineering has now released for circulation subject to certain qualifications. Only one such qualification affects the recommendations and this relates to 12.3 which the Director has instructed should have scale, responsibilities and timescales more clearly defined. A copy of the Report is attached.

I understand a copy of the Report should be passed to the Board's Insurers and have, therefore, marked two copies to the Director of Finance and Commercial Development.

I also understand that the Manager, Glasgow/Clyde Area has been asked for supplementary information on the Yoker Incident by the SEPD and for a synopsis of the Panels main findings by the Health and Safety Executive. Such information can now be extracted from the Report as necessary for these purposes and I would be pleased to receive a copy of the submissions.

R. M. GOVE
Chief Engineer Transmission/Distribution

Circulation:

Director of Engineering	(1)
Director of Finance and Commercial Development	(2)
(1 copy for the Insurers - Attn. Mr. C.G. Smart)	
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SOUTH OF SCOTLAND ELECTRICITY BOARD

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4TH MARCH 1980

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APPENDICES

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6 Summary of Statements by Mr. T. Craig and Mr. D. Cameron of Glasgow North District.

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7 Summary of Statements by Mr. W. Miller and Mr. G. McAllister, Control Engineers at the Glasgow/Clyde Area Distribution Control Centre.

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10 Report by Mr. J. Boyle, Engineer on Secondment to the Protection Section Project Sub-Group at Baillieston.

11 Transformer Tests Report.

13 Battery, Charger and 110V D.C. Supplies Report.

SOUTH OF SCOTLAND ELECTRICITY BOARD

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4TH MARCH 1980

1 INTRODUCTION

1.1 On the afternoon of Tuesday, 4th March 1980, 11 kV network switching was being carried out by engineers of Glasgow North District in order to locate a fault on 11 kV feeders supplied from Yoker Ferry Road substation.

1.2 By 16.45 hrs a faulty feeder had been isolated and the Bulldale Street circuit breaker at Yoker Ferry Road was to be closed to re-energise the local 11/0.415 kV transformer at Bulldale Street substation and the Lesmuir Place feeder out of Bulldale Street.

1.3 Immediately upon re-energisation, the substation lights went out, Bulldale Street substation began belching smoke and flames and this was followed a few seconds later by a major switchgear fault which rapidly developed along Section No. 1 of the Yoker Ferry Road 11 kV switchboard.

1.4 Although flags indicated that protection relays had operated, no 11 kV circuit breaker tripped to clear the fault which continued to be fed for approximately 14 minutes.

1.5 The Yoker/Partick No. 2 circuit breaker at Windyhill 132 kV substation tripped on overcurrent protection at 16.50 hrs in response to a consequential fault which had developed on transformer Grid T2 at Yoker.

1.6 The fault was finally cleared from the Grid at 16.59 hours when the Yoker/Partick No. 1 circuit breaker was opened by the substation attendant at Windyhill.

1.7 As a result, Yoker Ferry Road 132/11 kV substation and Partick 132/33 kV substation were disconnected from the Grid system with a total loss of supply of 38.5 MW at Yoker and 38 MW at Partick and affecting 33,000 consumers.

2 MEMBERSHIP

The membership of the Panel of Inquiry was as follows:-

Chairman - Mr. R.B. Howie, Electrotechnical Engineer

Mr. W. Watson, Plant Design Engineer

Mr. R. Cowan, Operations, Test & Protection Engineer, Glasgow/Clyde Area

Mr. A. Winter, Operations, Test & Protection Section, Glasgow/Clyde Area

Secretary - Mr. B. Law, Protection Section

3 TERMS OF REFERENCE

The terms of reference of the Panel of Inquiry were as follows:-

3.1 To investigate the cause of failure of supply to consumers and damage to equipment at Yoker Ferry Road substation on Tuesday 4th March 1980.

3.2 To consider the adequacy of arrangements at Yoker and at similar substations for containment of damage arising from faults, for rapid isolation of faulted equipment and for rapid restoration of supplies to consumers.

3.3 To consider the adequacy of access and fire containment arrangements at Yoker Ferry Road substation.

3.4 To make recommendations,

4 EVENTS LEADING UP TO THE MAIN INCIDENT

4.1 It should be noted in relation to the report given below that due to protection limitations, the circuit breakers at Bulldale Street substation controlling the Yoker Ferry Road feeder and the Lesmuir Place feeders are arranged to be non-automatic in operation.

4.2 Referring to Fig. 1, at 14.38 hrs on Tuesday 4th March 1980, a Distribution General Alarm was received at the Glasgow/Clyde Area Distribution Control Centre from Yoker Ferry Road 132/11 kV substation, followed at 14.50 hrs by complaints of no supply from Lesmuir Place and Kirkton Avenue. Mr. T. Craig and Mr. D. Cameron of Glasgow North District investigated the trouble, and in the course of switching operations, all of which were agreed with the Distribution Control Engineer, isolated the section from Yoker Ferry Road substation to Lesmuir Place substation via Bulldale Street substation, this feeder having been tripped out at Yoker Ferry Road by its associated inverse definite minimum time earth fault relay. Supplies to Blawarthill Hospital and parts of Anniesland were restored by closing the Cairntoul Drive switch at 135 Kirkton Avenue substation, the Lesmuir Place circuit breaker at Blawarthill Hospital substation having previously been opened.

4.3 The next step was to open the Yoker Ferry Road circuit breaker at Bulldale Street substation and then close the Bulldale Street circuit breaker at Yoker Ferry Road substation. This closure was successful and the circuit breaker was then tripped to enable dead switching to be carried out at Bulldale Street in pursuance of the fault. At Bulldale Street substation, the local transformer and Lesmuir Place circuit breakers were opened, the Yoker Ferry Road circuit breaker was closed, the South Street Yarrows circuit breaker was left closed and the Yoker Garage circuit breaker remained in its normally open position.

4.4 At Yoker Ferry Road substation, the Bulldale Street circuit breaker was reclosed at 16.30 hrs, with the agreement of the Control Engineer. The circuit breaker was immediately tripped out by its associated inverse definite minimum time earth fault relay, with a co-incident slight dip in the lights.

4.5 Deducing that the fault was on the South Street Yarrows feeder out of Bulldale Street substation, the associated circuit breaker at Bulldale Street substation was opened and the local transformer and Lesmuir Place circuit breakers at Bulldale Street substation were closed. At 16.45 hrs, with the agreement of the Control Engineer, the Bulldale Street circuit breaker at Yoker Ferry Road substation was reclosed.

5 DESCRIPTION OF THE MAIN INCIDENT

5.1 Immediately the Bulldale Street circuit breaker was closed, the lights in the control room went out, there were noises from outside the control room, and one of the engineers was aware of sparking and flashing from the wall-mounted control panel followed by sounds of an explosion outside. On vacating the control room, the engineers saw billowing brown smoke and flames emanating from Bulldale Street substation, then an explosion was heard from the centre of the No. 1 section of the switchboard at Yoker Ferry Road followed by extensive arcing at the switchboard.

5.2 Convinced that the whole switchboard was about to explode, the two engineers made their escape via the rear gate and Mr. Craig contacted a police patrol car near the ferry, asking them to relay a message to the Distribution Control Centre to have the grid incomers at Yoker Ferry Road tripped immediately. The police were also asked to keep the already gathering crowd back from the substation.

5.3 Mr. Cameron considered he could not safely get to the radio in his car, but Mr. Craig, having unsuccessfully tried two local telephones, finally got through to the Distribution Control Centre from a private telephone and asked the Control Engineer, Mr. G. McAllister, to "get the supply off the Grid transformers", and after a pause of around 20 secs., the Control Engineer reported that the supply to Yoker Ferry Road was now off.

5.4 Mr. Craig estimated that the total time from the inception of the fault to the final disconnection was approximately 15 minutes, the actual time when the Yoker/Partick No. 1 132 kV circuit breaker at Windyhill was manually opened being 16.59 hrs. The Yoker/Partick No. 2 circuit breaker at Windyhill had already been tripped by its associated inverse definite minimum time overcurrent relay at 16.50 hrs.

5.5 By the time the supply was removed, additional police had arrived and were in control keeping the public away from the substation. The fire service then arrived and were advised not to use water, so foam only was used.

5.6 The foregoing events are described in statements made by the two Glasgow North District Engineers, Appendix 6, and in statements made by the two Distribution Control Engineers, Appendix 7. Additional statements relating to operations carried out by the Windyhill Transmission engineers, R.T.F. Melrose and D. Swanson, are attached as appendices 8 and 9 respectively. A report by J. Boyle, an engineer on secondment to the Baillieston Protection Sub-Group is attached as Appendix 10. The NJB and NJIC Safety representatives for Glasgow North District and the Windyhill Transmission Group were invited to submit their comments on the incident and a response was received from two of them.

5.7 Some confusion seems to have arisen concerning the emission of smoke and/or steam around the voltage transformer on Grid 2 circuit breaker some 30 mins. after the Yoker Ferry Road 11 kV switchboard had been made dead. The police had queried whether the switchboard had been re-energised, but the Panel of Inquiry are satisfied that this was not the case. The Panel also agreed that the smoke or steam which was observed had emanated from the seat of the fault and could have worked its way through the space between the weather-proof cladding and the busbar chambers ultimately to escape in the vicinity of/

of the Grid 2 voltage transformer.

5.8 Copies of the preliminary Grid fault reports SS 1979/80 - 154, 155 and 156 are attached as Appendix 1.

5.9 Extracts of the Distribution Control Centre log sheets 1368 and 1369 are given in Appendix 2.

5.10 Extracts of the Windyhill Grid substation log sheet are given in Appendix 3.

5.11 Extracts of the log sheets of the Grid Control Centre, Strathkelvin House, are given in Appendix 4.

5.12 Distribution and Transmission protective gear operations including fault currents and relay operating times are given in Appendix 5.

6 LOSS OF SUPPLY

6.1 The fault resulted in the complete loss of all supplies from Partick 132/33 kV substation as well as from Yoker Ferry Road substation affecting 33,000 consumers with a total demand of 78.5 MW for a period of 43 mins. from 16.45 hrs, the inception of the fault to 17.28 hrs. when Grid 1 33 kV circuit breaker at Partick was reclosed to restore supplies to 20,000 consumers having a demand of 38 MW in Partick, Kelvinside and parts of Scotstoun.

6.2 At 20.25 hrs, 9,000 consumers having a demand of 11 MW in various parts of Knightswood, Scotstoun and Clydebank were reconnected, having been without supply for 3 hrs. 40 mins.

6.3 At midnight, a further 1,100 consumers having a maximum demand of 2 MW in various parts of Yoker and Scotstoun were reconnected, having been without supply for 7 hrs. 15 mins.

6.4 At 07.00 hrs. on Wednesday 5th March, 2,500 consumers having a maximum demand of 12.5 MW in various parts of Yoker, Scotstoun and Clydebank, including Marathon and John Brown Engineering, were reconnected, having been without supply for 14 hrs. 15 mins.

6.5 At 16.30 hrs. 500 consumers having a demand of 12.5 MW, including six large engineering consumers in Yoker, were reconnected, having been without supply for 23 hrs. 45 mins.

6.6 The remaining 50 consumers, having a demand of 0.5 MW were finally reconnected 29 hrs. 5 mins. after the inception of the fault at 21.50 hrs. on Wednesday 5th March 1980.

7 EXTENT OF DAMAGE

7.1 Bulldale Street Substation

7.1.1 The five panel switchboard and the wall-mounted relay panel were extensively damaged and will have to be replaced. Fig. 5 (a) shows the destruction of the cable termination and lower isolator of the Lesmuir Place panel, and Fig. 5 (b) shows the damage to the busbars. Full details of the damage are given in Appendix 11, Switchgear Damage Report.

7.1.2 The 415/240V switchboard situated on the wall opposite the 11 kV switchgear was damaged beyond repair as was the substation internal wiring.

7.2 Yoker Ferry Road 132/11 kV substation

7.2.1 Of the twelve panels of Section 1 of the 11 kV switchboard, eight panels were damaged beyond repair, the Bulldale Street panel, No. 13 in Fig. 1, being totally destroyed. The accompanying photographs, Figs. 6 (a) - 6 (g) inclusive, show the damage to the switchboard, this being fully described in Appendix 11, Switchgear Damage Report.

7.2.2 Fig. 6 (a) is a general view of the front of Section 1, while Fig. 6 (b) depicts the complete destruction of the busbars of the eight panels referred to above.

7.2.3 Fig. 6 (c) shows the destruction caused to the cable boxes on panel No. 11, Grid 1, and panel No. 13, Bulldale Street, and Fig. 6 (d) shows the extent of the damage to the current transformer chamber and busbar chamber of panel No. 09, Clydeholme Terrace. (The panel numbers are as shown in Fig. 1).

7.2.4 Fig. 6 (e) is a view of the moving contact assembly of the Bulldale Street feeder circuit breaker which was found in the bottom of the tank, and Fig. 6 (f) is a view of the Bulldale Street circuit breaker tank which shows clearly that it has retained its circular shape which indicates that it was not subjected to any excessive internal pressure.

7.2.5 Fig. 6 (g) is a photograph of the mechanism removed from the Bulldale Street circuit breaker panel.

7.2.6 Grid Transformer No. 2 developed an internal fault which, while not as yet fully explained, is considered to be related to the passage of fault current of 3.5 to 4 times full load for 5 minutes. The internal pressures so generated caused the tank to bulge as shown in the photographs in Fig. 4.

7.2.7 Grid Transformer No. 1 was thoroughly examined and tested and accepted to be fit for further service. Section 8.4 of this Report gives details of the examinations and tests carried out on the transformers, the test results for transformer No. 1 being detailed in Appendix 12, Transformer Test Report.

7.2.8 The 11 kV reactors associated with Grid Transformers 1 and 2 were examined as described in Section 8.5 of this Report and accepted as fit for further service.

7.2.9/

7.2.9 Samples of the 11 kV cables between Grid Transformer No. 1 and Grid 1 11 kV circuit breaker revealed no evidence of damage, either mechanical or thermal, Section 8.6 of this Report giving fuller details of the samples taken.

8 FAULT INVESTIGATION

8.1 Protection

8.1.1 On the occurrence of the original fault affecting the Bulldale Street circuit out of Yoker Ferry Road 132/11 kV substation, the inverse definite minimum time overcurrent and earth fault protection on the Bulldale Street feeder panel at Yoker Ferry Road substation operated on earth fault and tripped the circuit breaker. Similarly, the first reclosure on to a faulty feeder out of Bulldale Street substation resulted in the Bulldale Street circuit breaker at Yoker Ferry Road substation being tripped again by the same earth fault relay. These relay operations indicate the presence of a single-phase earth fault.

8.1.2 The final reclosure of the Bulldale Street circuit breaker at Yoker Ferry Road substation resulted in the operation of both overcurrent elements and the earth fault element of the inverse definite minimum time relay on the Bulldale Street feeder panel, but on this occasion, the circuit breaker failed to trip. These relay operations indicate the presence of a three-phase fault.

8.1.3 Section 1 of the 11 kV switchboard at Yoker Ferry Road substation then developed a busbar fault which resulted in the operation of the red, yellow and blue phase fault elements of zone 1 of the busbar protection along with the neutral check relay, but again, no circuit breakers were tripped. Operation of the trip supply failure relays on zones 1, 2 and 3 of the busbar protection indicated a loss of the 110V d.c. trip supply to the switchboard.

8.1.4 It is assumed that the inverse definite minimum time overcurrent relays on Grid 1 and Grid 2 11 kV panels would have operated as back-up protection to the Bulldale Street feeder protection, but the flags on these relays are operated by an integral combined flag indicator and shunt trip reinforcing contactor which requires the 110V d.c. trip supply for its operation, and no flag indications were recorded. The relays also trip the circuit breaker directly as well as via the tripping contactor, but no tripping of either Grid 1 or Grid 2 11 kV circuit breakers occurred. Indications were received at the Distribution Control Centre that Grid 1, Grid 2 and Grid 3 tripping and intertripping supplies were faulty.

8.1.5 On the 132 kV side of transformers Grid T1 and Grid T2, the H.V. overcurrent protection operated but did not trip the associated 11 kV Grid circuit breakers at Yoker Ferry Road nor intertrip to the 132 kV substation at Windyhill.

8.1.6 Not until transformer Grid T2 developed a winding fault did the overcurrent protection operate at Windyhill and trip Yoker/Partick No. 2 circuit breaker (705), and intertrip Partick Grid 2 33 kV circuit breaker. An intertrip was also received at Yoker but the lack of 110V d.c. supply prevented Grid 2 11 kV circuit breaker being tripped.

8.1.7 Appendix 5 gives details of all the protection operations and the indications and alarms received at Yoker Ferry Road substation, the Distribution Control Centre, Windyhill 132 kV substation, Partick 132/33 kV substation and Grid Control. It also includes calculations of relay operating times at Yoker Ferry Road and Windyhill substations.

8.2 D.C. Supplies

8.2.1 Examination of the fuses in the 110V d.c. supply circuits revealed that the main battery + ve fuse was open-circuited and the other two fuses, although intact, exhibited signs of deterioration due to oxidation resulting from thermal cycling due to fluctuating load. Fig. 7 is a photograph of the elements of the three fuses after removal from the fuse holders.

8.2.2 Appendix 13, which is concerned with the 110V battery, charger and d.c. supplies, describes the probable cause of the deterioration/open-circuiting of the main battery fuses. The appendix considers that the main battery + ve fuse finally went open-circuit at the end of the last closing operation of a solenoid-closed circuit breaker, i.e. on 28th February 1980, thus leaving the d.c. tripping supplies fed only from the battery charger for five days up to the fault incident.

8.2.3 In support of this conclusion, it was noted that after the main battery fuses had been rewired and replaced, restoration of the 415/240V a.c. supply to the substation resulted in a battery charge of around 43A for some time before decaying slowly, indicating that the battery was in a low state of charge.

8.2.4 It is significant that the Bulldale Street circuit breaker tripped correctly on the initial earth fault and again on the first reclosure on to the fault, with a slight co-incident dip on the substation lights. The next reclosure, which was on to a three-phase cable fault, resulted in the collapse of the 415/240V a.c. supply to the substation as "the lights went out immediately". Under these conditions there would be no d.c. output from the charger to trip the circuit breaker. This is because the a.c. input to the charger would also have collapsed since it is fed from the same source of supply as the substation lighting, namely the earthing transformer of Grid Transformer No. 3.

8.3 Switchgear

8.3.1 After the incident, a full investigation was carried out to determine the extent and cause of the damage to the five panel 11 kV switchboard at Bulldale Street substation and to the 27 panel 11 kV switchboard at Yoker Ferry Road substation.

8.3.2 Full details of the damage, with supporting evidence, are given in Appendix 11, Switchgear Damage Report, which confirms that the design, manufacture and operation of the switchgear in no way contributed to the destruction of eight panels of the switchboard. The damage was entirely due to the switchgear being subjected to operating conditions far beyond its specification due to the loss of the 110V d.c. tripping supply.

8.4 Transformers

8.4.1 All transformers are 132/11 kV, 30 MVA rating, T1 and T3 having been manufactured by Parsons Peebles Power Transformers Ltd., (PPPT Ltd), serial Nos. 43162 and 43163. T2 was manufactured by Ferranti Ltd., serial No. 163100.

8.4.2 At the time of the fault incident at Yoker Ferry Road substation, T1 and T2 were on load with T3 on standby as a "swinger" unit with its 11 kV circuit breaker closed and the 132 kV switching isolators 118 and 218 open.

8.4.3 The effect of the fault on the two loaded transformers was as follows:-

8.4.3.1 Transformer No. 1 (PPPT Ltd)

This transformer exhibited no outward signs of distress. On 6th March 1980, PPPT Ltd., visited the site to carry out electrical tests on the transformer to check the integrity of the windings. Turns ratios were measured along with low voltage magnetising currents, winding resistances and insulation resistances, all of which indicated that the windings had not suffered distress. These test results are detailed in Appendix 12, Transformer Test Results. Gas-in-oil analysis results of samples from the transformer and the tap-changer selector tanks were satisfactory, the results also being included in Appendix 12.

On 17th March, PPPT Ltd., again visited the site to carry out an inspection of the winding clamping structure. With the oil lowered to expose the top winding insulation and clamping arrangement, the top assembly was scrutinised from outside through appertures in the tank top, and physically checked for tightness by a representative of PPPT Ltd., entering the tank. All clamping screws and packing blocks were found to be secure. The tank was refilled with oil and the complete oil filling subjected to ILOVAC treatment. It is considered that the transformer is sound and can be returned to service although, if possible, it would be prudent to energise the transformer initially from a controllable voltage source.

8.4.3.2 Transformer No. 2 (Ferranti Ltd.)

The oil pressure release vent diaphragm had fractured and a considerable quantity of oil had been ejected, (to a depth of several inches within the oil-retaining wall), and in addition, the tank was bulged outwards, all indicative of a considerable disruptive force within the tank. Fig. 4 contains photographs showing the deformation of the tank.

On 6th March 1980, hand hole covers were removed on the tank top to permit an internal examination. This revealed that the transformer windings had suffered considerable damage and would need complete replacement, as would the main tank. This assessment was endorsed by PPPT Ltd., who are acting for Ferranti Ltd., who have now ceased manufacturing transformers.

8.5 Reactors

8.5.1 Three fault limiting reactors, each of 30 MVA rating, 11 kV, are installed, one between each Grid transformer and its associated 11 kV circuit breaker.

8.5.2 Oil samples taken from reactors R1 and R2 for gas-in-oil analysis indicate that no distress was suffered during the incident. An internal examination of reactors R1 and R2 was carried out on 25th March 1980 and revealed no evidence of distress. It must therefore be assumed that the reactors are fit for service.

8.6 Cables

8.6.1 Yoker Ferry Road Substation

8.6.1.1 The Grid 1, Grid 2 and Grid 3 11 kV circuit breakers are each connected to their respective 132/11 kV transformers, (via the reactors), by 3 x 800 sq.mm. copper conductored single core 11 kV cables per phase. The cables, which are paper insulated, lead sheathed and PVC served, are buried direct in the ground.

8.6.1.2 Following the fault incident, an examination was made of the cables between Grid 1 11 kV circuit breaker and reactor R1. The cable samples, (nine in total), were obtained at a distance of approximately eight metres from Grid 1 circuit breaker and at a buried depth of approximately two metres.

8.6.1.3 An examination of three samples selected at random revealed that the cables had not been damaged either mechanically or thermally as a result of the fault. A visual examination of the cable sheath at transformer No.2 and transformer No. 3 terminations was also carried out and again, did not reveal any thermal damage. (A severe overload condition would have left visible evidence on the PVC sheath). The remaining six samples were thoroughly examined and again, no signs of either mechanical or thermal damage were found.

8.6.1.4 In support of these findings, calculations based on a 5 kA overload for 15 mins. indicate that the cables are fully capable of sustaining this load without damage.

8.6.2 Bulldale Street Substation

8.6.2.1 Two feeders out of Bulldale Street substation were involved in the fault incident, the South Street Yarrows feeder and the Lesmuir Place feeder.

8.6.2.2 The South Street Yarrows feeder fault occurred 300 metres from Bulldale Street substation at a point where a stake had been driven into the ground and then removed, damaging the cable at the time, although this had not caused the circuit to trip out then. The type of cable involved at the fault position is 0.2 sq.in. copper conductored, unarmoured, paper insulated, lead covered and laid in pitch and troughing.

8.6.2.3 The fault on the Lesmuir Place feeder originated immediately outside the wall of Bulldale Street substation and due to the ducts in the wall not being sealed, the arcing products of the fault were propagated into the cable termination and isolator compartment of the Lesmuir Place circuit breaker in the substation. The type of cable at the fault position is 0.2 sq.in. copper conductored, paper insulated, lead covered and steel tape armoured.

8.6.2.4 The incoming cable from Yoker Ferry Road substation to Bulldale Street substation is 185 sq.mm. CORAL aluminium conductored, aluminium sheathed, and it was noted that the aluminium sheath had split open for at least one metre from the cable box of the Bulldale Street circuit breaker at Yoker Ferry Road Substation.

8.6.2.5/

8.6.2.5 From the observations of the Glasgow North District engineers, (Appendix 6), that a slight smell of burning was noticed on first entering Bulldale Street substation in pursuance of the original fault, it is possible that the original fault was an earth fault on the Lesmuir Place feeder. Because the 11 kV system at Yoker Ferry Road is resistance earthed, the voltage on the two healthy phases would be increased to a level approaching the phase-to-phase voltage, and this elevated voltage could well have caused the damaged section on the South Street Yarrows feeder to flash over, leaving the cable in a faulty condition. This fault was then found in the subsequent sectionalising, leading the engineers to the natural conclusion that they had found the cause of the original fault trip. Subsequent closure on to the Lesmuir Place feeder resulted in the original earth fault being immediately converted into a two or three phase-to-earth fault which collapsed the a.c. voltage supply to the battery charger at Yoker Ferry Road substation.

9 SITE CONSIDERATIONS

9.1 The 11 kV switchboard at Yoker Ferry Road substation runs parallel to the boundary fence on Yoker Ferry Road, and the back of the switchboard is approximately 8 metres from this fence, (see Fig. 2).

9.2 The separation of the switchboard from the general public by a screening wall was considered by the Panel in relation to the following facts:-

9.2.1 The switchgear was subjected to operating conditions which were far beyond its specified short-circuit withstand capability of 13 kA for 3 secs, which is the nationally accepted standard for 11 kV switchgear. Despite the length of time that the fault current was flowing, the switchgear did not explode but only burned due to arcing, and there were no injuries either to the general public or to SSEB personnel.

9.2.2 Throughout the SSEB there is a wide variety of plant in use, switchgear, transformers and the like, which is in close proximity to the general public. Despite the occurrence of faults on such items as cable boxes and switchgear busbar band joints, there is no record of injuries to the general public having been reported.

9.3 As regards the containment of the damage to the switchgear, (Section 3.2), had the switchgear at Yoker Ferry Road substation been of the compound-filled type with inter-panel barriers and interconnecting bushings, it is the considered opinion of the Panel that due to the length of time that the fault persisted, the busbars would have been destroyed along most if not all of the length of Section 1 in any case. The total damage may even have been worse as the compound would have added fuel to the fire, and blazing compound dripping down around the circuit breaker tanks may well have resulted in these oil-filled tanks exploding.

9.4 Concerning the question of the adequacy of access to Yoker Ferry Road substation, (Section 3.3), this arose due to a misleading report to the Chief Engineer, Transmission/Distribution which stated that the fire brigade had had to ask for the 132 kV line to be switched out to enable them to gain access to the substation compound. This was not the case, as the line was switched out at the request of the Glasgow North District engineers via the Distribution Control Centre to remove the supply from the fault, (see Appendix 6, page 2). The fire brigade were well able to attack the fire from the road, gaining access to the compound by the personnel gate in the fence which the engineers had used during the switching operations preceding the main fault incident.

10 CONCLUSIONS

10.1 The damage to the transmission/distribution plant at Yoker was due to the very slow clearance of a three-phase fault on the Lesmuir Place 11 kV cable circuit out of Bulldale Street substation. The fault current ultimately gave rise to overheating of the isolating contacts on the Bulldale Street unit of the Yoker Ferry Road 11 kV switchboard followed by burning and sustained arcing which was self-propagating along the entire length of the No. 1 section. Any consequential explosive effects were of a minor nature and unrelated to the circuit breakers being of the oil type.

In the case of Bulldale Street substation, a similar process was initiated by debris, etc. from the cable fault being blown back along the duct into a circuit chamber of the switchgear.

The precise mode of failure of transformer Grid T2 is not known at this time, but was clearly related to the prolonged passage of fault current.

10.2 The very slow clearance of the fault was due to the failure of all 110 V d.c. tripping/control supplies at the time of the incident. The tripping supply up to this time was being maintained by the 110 V d.c. battery charger since one of the main battery rewireable fuse-elements had gone open-circuit some days previously. At the time of the incident, the three-phase fault collapsed the voltage of the locally derived auxiliary supplies resulting in the battery charger output falling to zero.

10.3 The open-circuiting of the main battery fuse, which was inadequately rated, was induced by progressive deterioration of the rewireable fuse-element and is believed to have occurred at the time of the last closing operation of a 2,000 A solenoid-closed 11kV circuit breaker at Yoker Ferry Road on 23 February 1930. The conditions of these fuses is not automatically monitored, and the battery manual test facilities are not comprehensive.

10.4 The inadequacy of the main battery fuse rating and the lack of co-ordination with sub-circuit fusing appears to date back to 1974/75 when the "swinger" transformer Grid T3 was installed at Yoker and the 11 kV switchboard was established at Yoker Ferry Road, It should have been realised at that time that this reinforcement would result in increased switchgear closing duty on the 110 V battery, but failure to take the necessary action appears to have stemmed from inadequate liaison between the Transmission Construction Section carrying out the new work and the Transmission Operation and Maintenance Section responsible for the then existing operational plant on the site.

It is acknowledged that in 1973, a "Manual of Site Commissioning Procedures" was introduced which should obviate this type of oversight in the future.

10.5 All pre-incident and post-incident switching operations were carried out as per Control instructions and in accordance with the Board's Safety Rules.

10.6/

10.6 This low probability fault subjected the 11 kV switchgear to a current-carrying duty very much in excess of specification, yet its mode of failure did not result in injury either to Board staff or to the general public. The Board's record in public safety in relation to substation operation is very good, and the Panel can find no justification for the erection of a physical barrier between the 11 kV switchgear and the public footpath at Yoker Ferry Road.

10.7 The access to Yoker Ferry Road 11kV substation and to Yoker 132 kV Grid substation is considered adequate.

11 ACTIONS ALREADY TAKEN

11.1 Following the fault incident, the three main battery fuses were rewired with eight strands of 15 A fuse wire giving a rating of 120 A. These have since been uprated to 180 A using two strands of 0.072 in (15 SWG) copper wire.

11.2 Instructions have been issued to the Protection Engineer, (for Generating stations), the Transmission Operation and Maintenance Engineer, (for Transmission substations) and to the Area Engineers, (where appropriate in joint-user substations), to check all rewireable fuses in battery circuits and to check the co-ordination of fuses in battery supplies to closing and tripping circuits.

12 RECOMMENDATIONS

In the light of all the evidence taken regarding the events leading up to the main incident as well as the main incident itself, the Panel made the following recommendations:-

	ACTION
12.1 The main battery fuses should be monitored so that in the event of a fuse blowing or otherwise going open-circuit an alarm is given immediately. Alternatively, in place of the fuses, self-monitoring protection, e.g. a d.c. circuit breaker fitted with overcurrent trip coils and auxiliary contacts should be provided.	Plant Design Engineer
12.2 Test circuits on the d.c. board should be arranged to monitor the condition of the battery as opposed to the d.c. busbars.	Trans. O & M Engineer
12.3 The fusing policy, including co-ordination, type of fuse etc, for tripping and closing circuits in Transmission/Distribution circuits should be reviewed.	Protection Engineer
12.4 Transmission Plant Standard 9/3 relating to 110V d.c. power supplies in substations should be examined to determine whether the present arrangement of the charger and battery is adequate, or if modifications are required.	Plant Design Engineer
12.5 Alternative back-up tripping facilities for Transmission/ Distribution substations should be examined, such as:-	Protection Engineer
(a) separate batteries for tripping and closing,	
(b) separate battery for intertripping,	
(c) separate batteries for Transmission and Distribution use,	
(d) a.c. series trip coils operated in conjunction with the inverse definite minimum time overcurrent relays on Grid l.v. incoming circuit breakers. This is current policy for primary substation transformer circuit breakers. (Distribution Protection Manual, Volume 1, Section 1.4.5.	
12.6 All cable entries into substation buildings should be checked to ensure that they are adequately sealed against the ingress of gas, etc. into the premises and that the Board's policy in relation to this has been fully implemented.	Trans. O & M Engineer & Area Engineers
12.7 This incident illustrates the importance of the control engineers at the Distribution Control Centres having a complete picture of the transmission network supplying their respective Areas. The remote indication of Windyhill substation at the Glasgow/Clyde Area Distribution Control Centre has been authorised for some time and should now be assigned a higher priority.	Telecomms. Engineer
12.8 The incident lends support to the argument that data loggers should be provided in the Distribution Control Centres to record the sequence of events, preferably in real time. This would greatly ease the problems of post-incident analysis.	Distribution Engineer

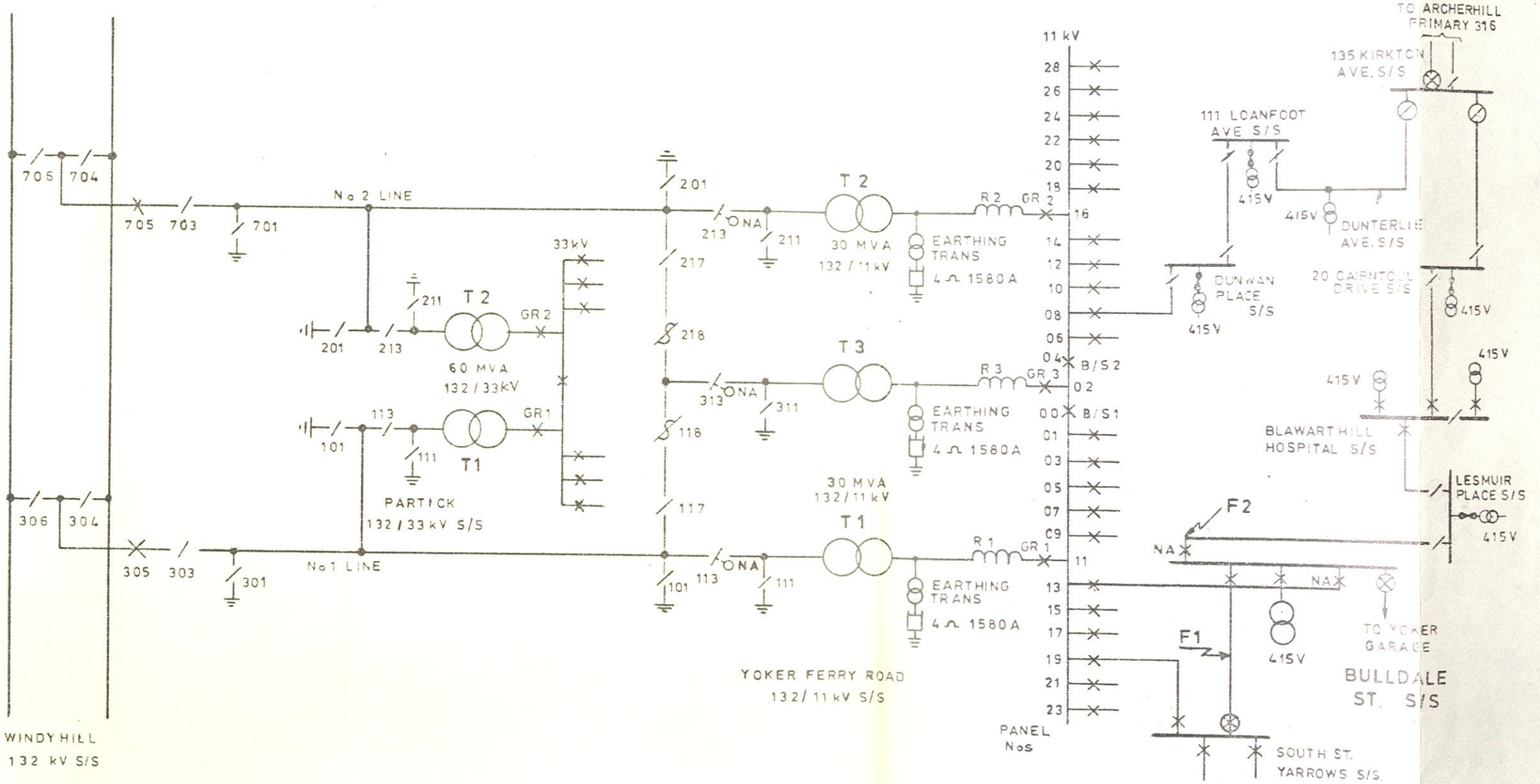
Notes/

ACTION

Notes

(1) Where applicable, the aforementioned recommendations should be applied to all Transmission and Distribution Substations.

(2) Although the actions have been allocated to specific Departmental, Branch or Section Heads, collaboration with other Branches or Sections will be required for some if not all of the recommendations.



NOTES

NORMALLY OPEN CIRCUIT BREAKER

NON - AUTOMATIC CIRCUIT BREAKER

AUTOMATIC SWITCHING ISOLATOR

NORMALLY OPEN OIL SWITCH

FAULT 1 WAS 300 METRES FROM BULLDALE ST. S/S

FAULT 2 WAS ALONGSIDE WALL OF BULLDALE ST. S/S

AT YOKER FERRY ROAD S/S

CIRCUIT BREAKERS GRID 1 GRID 2 AND GRID 3 NORMALLY CLOSED

SWITCHING ISOLATORS 118 AND 218 NORMALLY OPEN

ISOLATORS 113, 213, 313, 117 AND 217 NORMALLY CLOSED

REVISION	DATE	DRAWN	CHECKED	APPROVED

SOUTH OF SCOTLAND ELECTRICITY BOARD

BOARD HEADQUARTERS
CATHCART HOUSE
GLASGOW G44 4BE

OFFICE OF ORIGIN

DESCRIPTION OR TITLE

NETWORK DIAGRAM OF YOKER FERRY ROAD 132/11 kV SUBSTATION INCLUDING GRID SUPPLIES AND FAULTED 11 kV NETWORK AS AT 4th MARCH 1980

LOCATION:

SCHEME CONTRACT JOB No.			
DRAWN	CHECKED	APPROVED	AUTH'D.
B.L.			
26-3-80			

REVISION

No OF SHEETS | SHEET No.

DRG. No. FIG 1

SCALE
DRAWN

A2

0389

OZALID L 2417

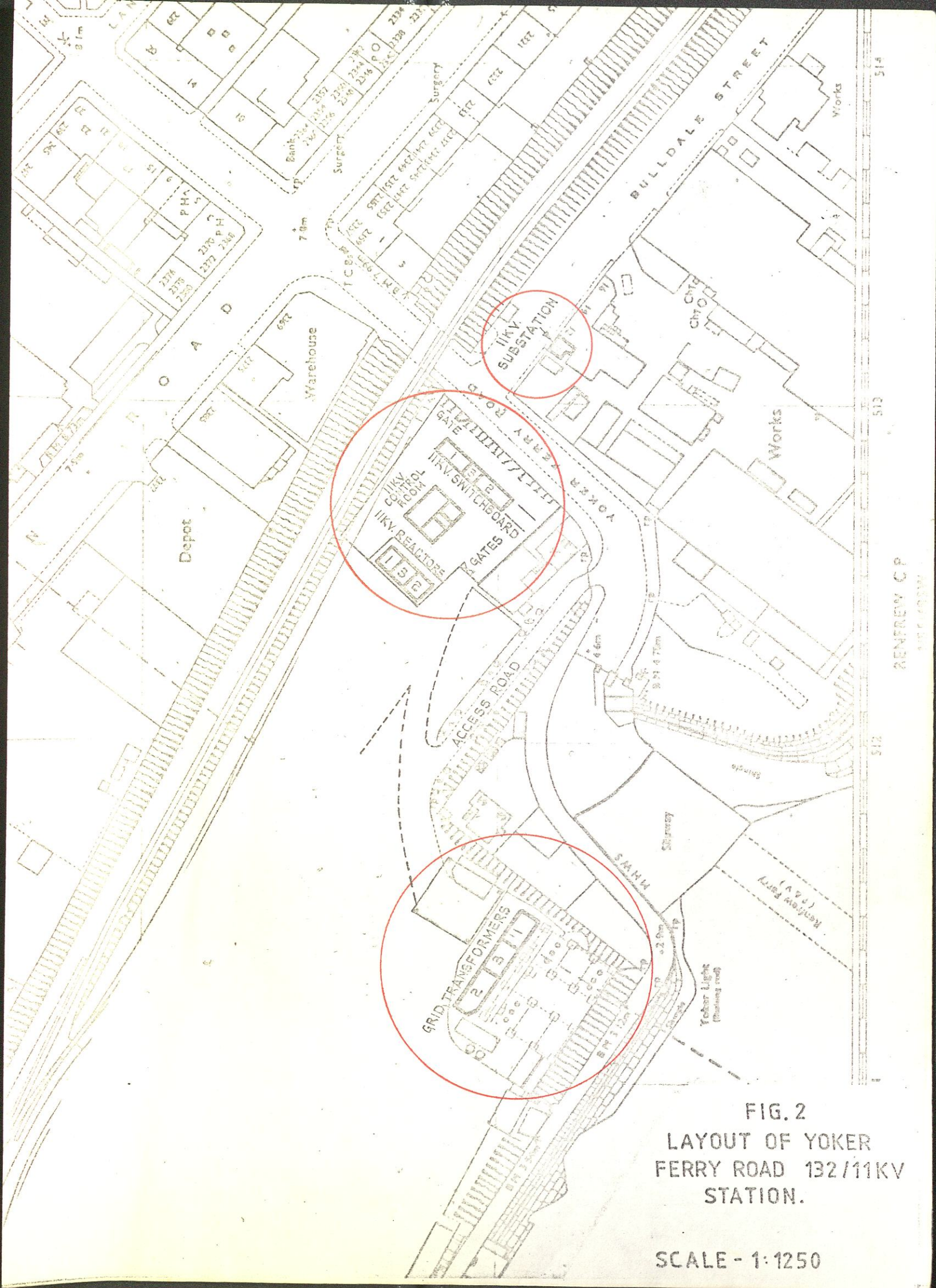
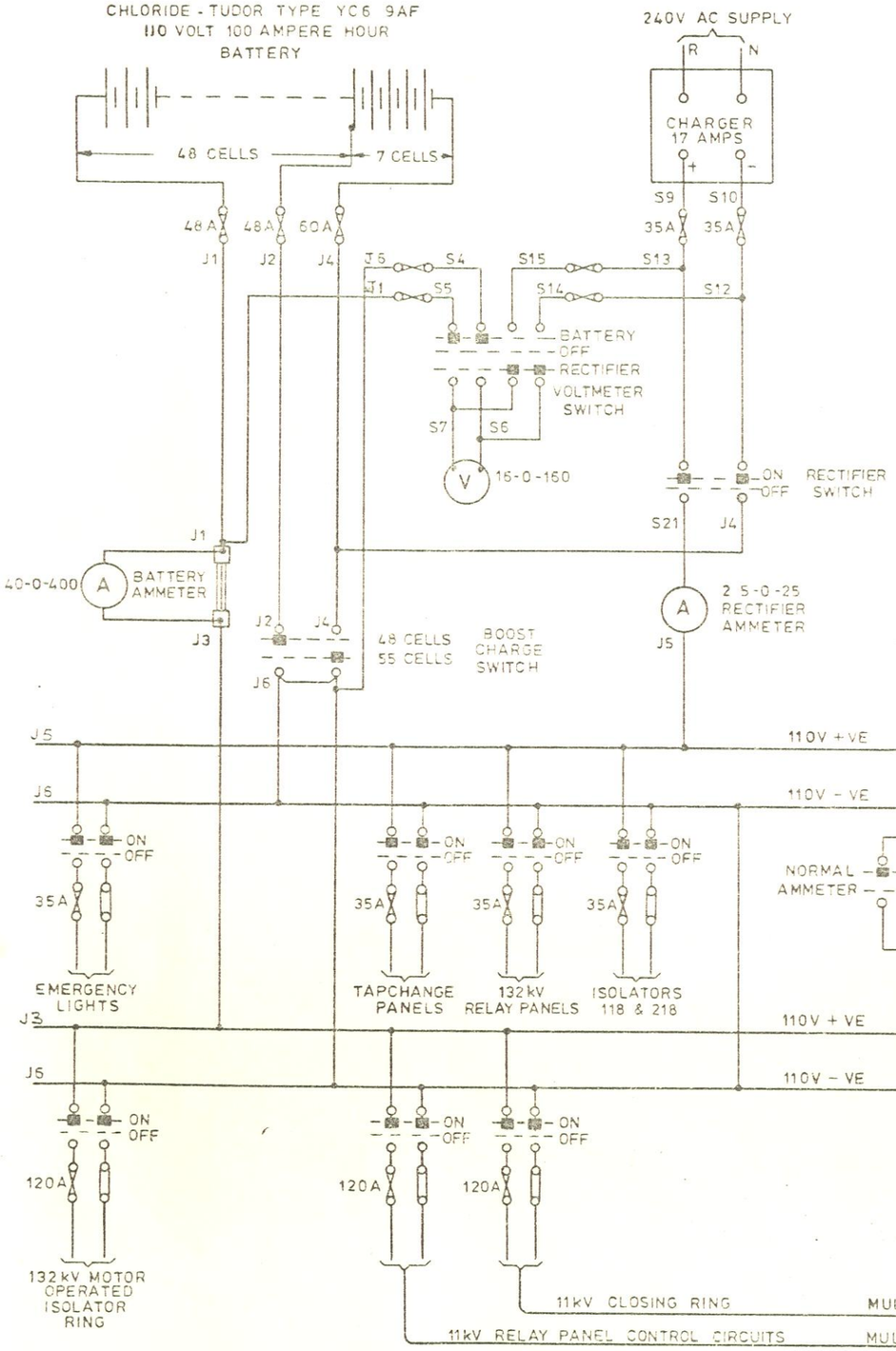


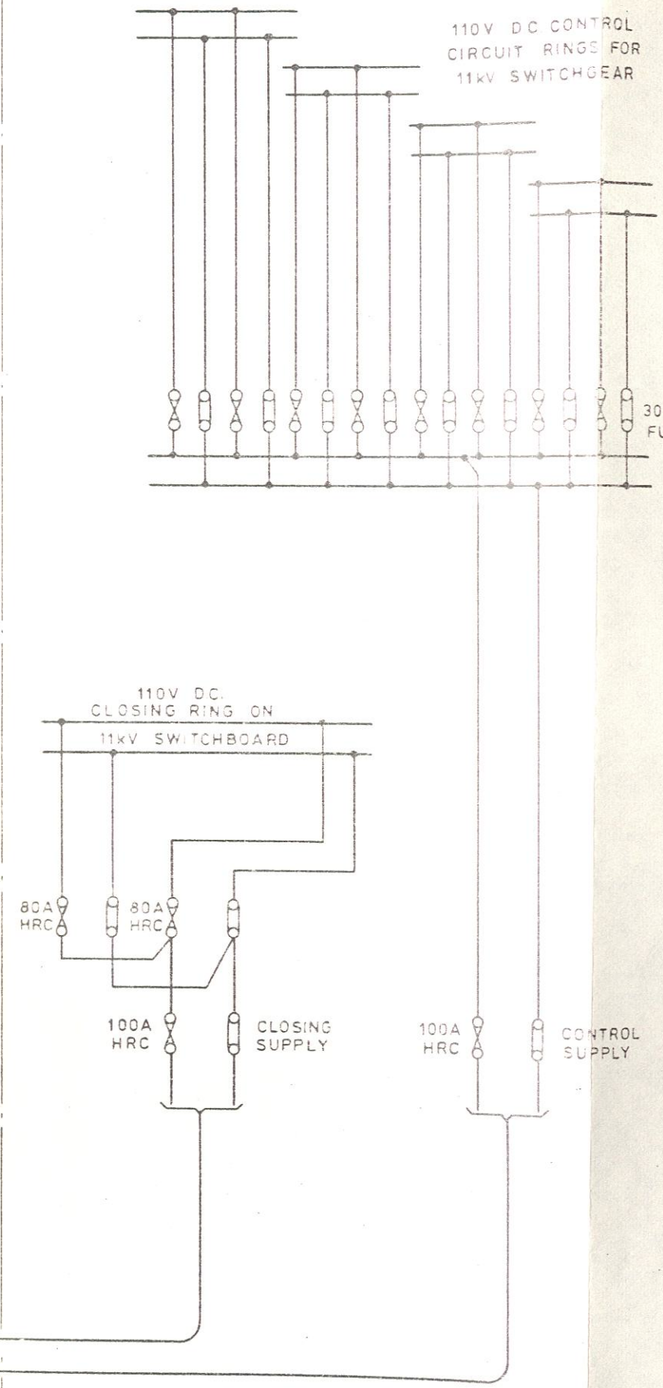
FIG. 2
LAYOUT OF YOKER FERRY ROAD 132/11KV STATION.

SCALE - 1:1250



NOTES 1. ALL FUSE CARRIERS ON BATTERY, RECTIFIER AND MAIN D.C BOARD ARE REWIREABLE
2. FUSE RATINGS AS AT 4th MARCH 1980
3. NEGATIVE BIAS CIRCUITS OMITTED FOR CLARITY

132 kV SUBSTATION



11kV SUBSTATION

FIG 3

REVISION	DATE	DRAWN	CHECKED	APPROVED

SOUTH OF SCOTLAND ELECTRICITY BOARD

BOARD HEADQUARTERS
CATHCART HOUSE
GLASGOW G44 4BE

OFFICE OF ORIGIN

DESCRIPTION OR TITLE

DIAGRAM OF BATTERY, CHARGER AND D.C. CIRCUITS AT YOKER FERRY ROAD 132 / 11kV SUBSTATION

LOCATION:

SCHEME CONTRACT JOB No.

DRAWN	CHECKED	APPROVED	AUTH'D.
BL			
9-4-80			

REVISION

No OF SHEETS | SHEET No.

DRG. No. FIG 3

SCALE DRAWN A3

074UD 12417

0389T

YOKER GRID SUBSTATION
GRID TRANSFORMER NO.2

Fig 4a End view of transformer

Fig 4b Rear of transformer showing bulge

YOKER GRID SUBSTATION
GRID TRANSFORMER NO.2

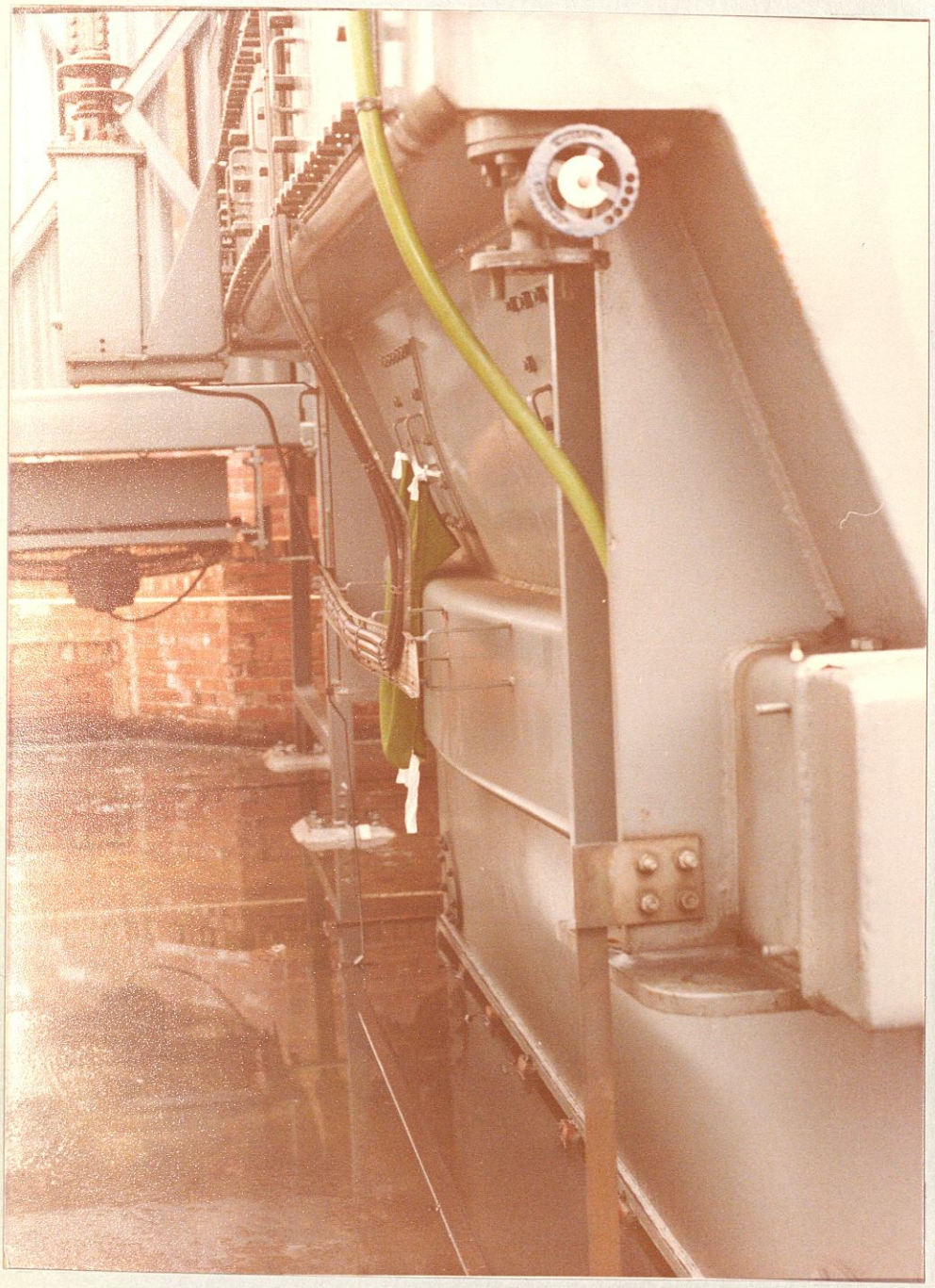


Fig 4c

Front of transformer showing bulge

Fig 4d Close-up of bulge on front of transformer

Fig 5a View showing destruction of cable termination/lower isolator compartment of Lesmuir Place panel

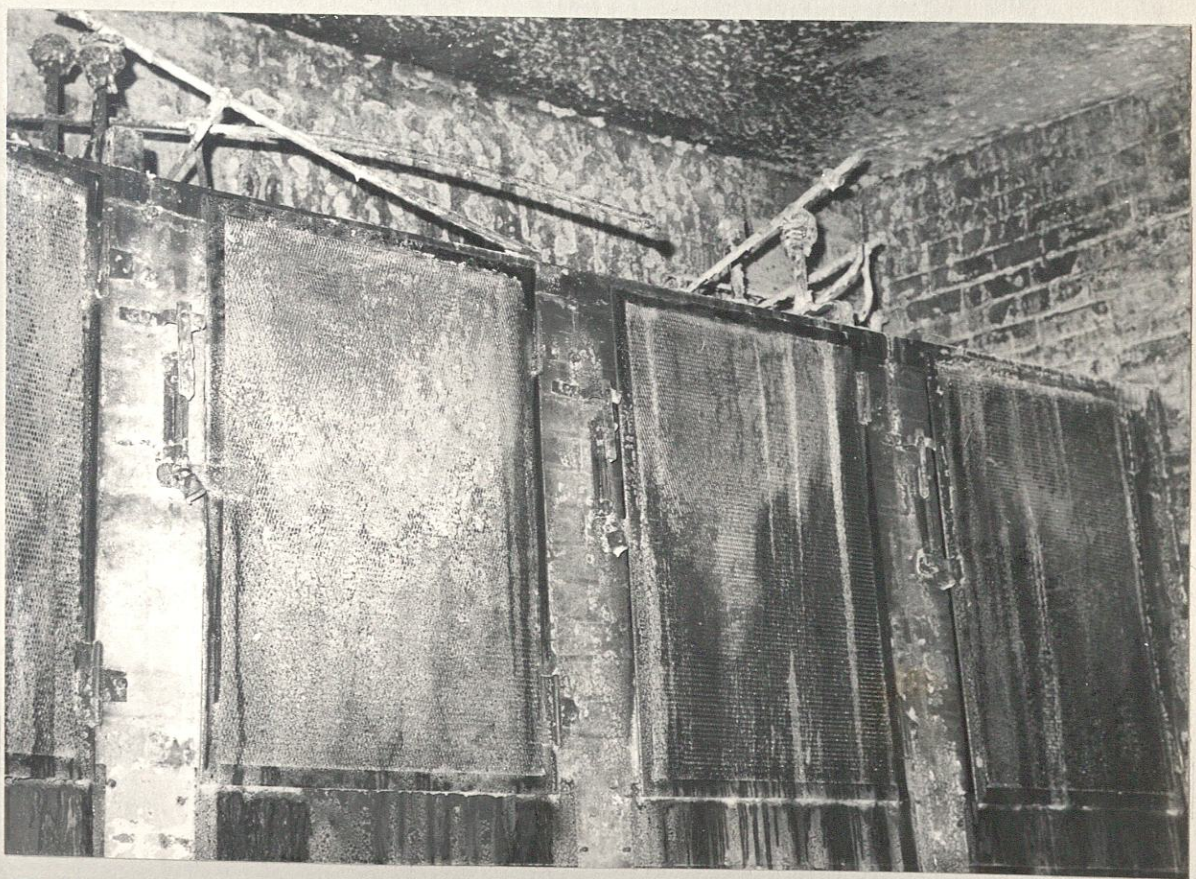


Fig 5b View showing damage to bus bars

Fig 6a Front view Section 1 of switchboard

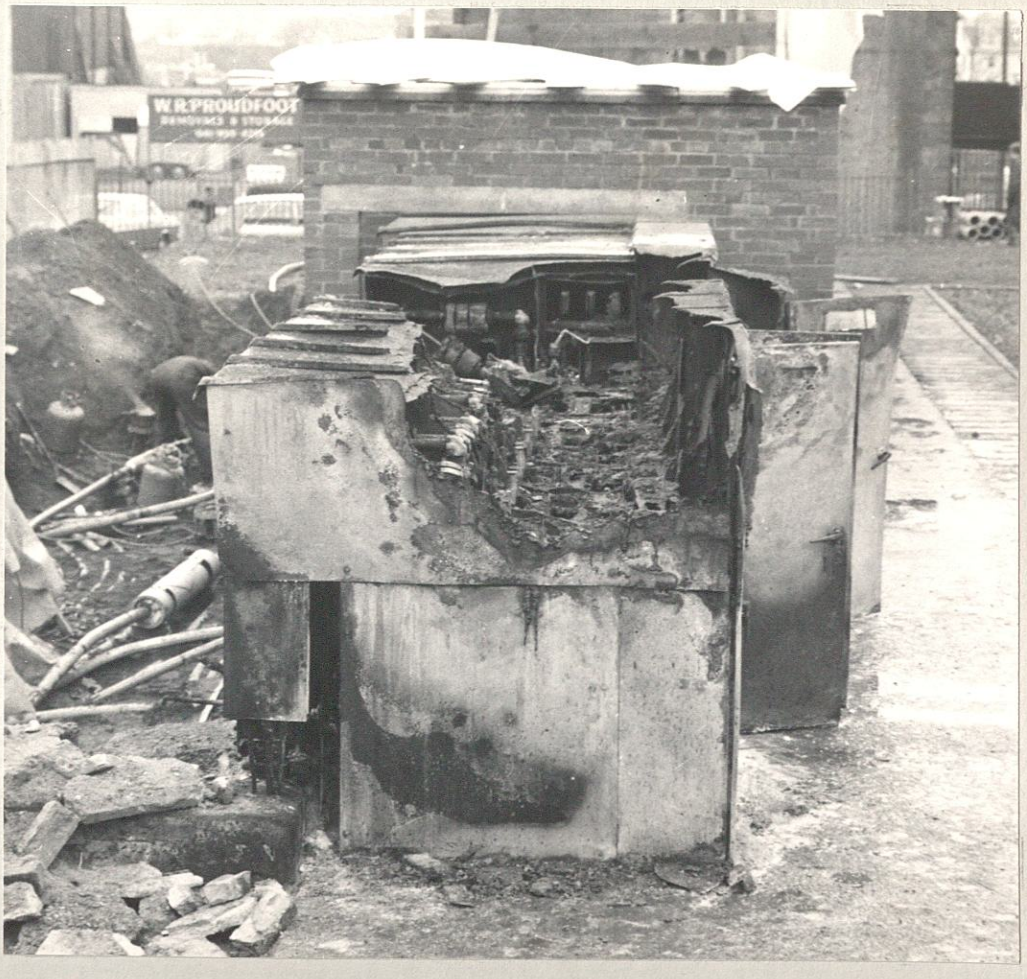


Fig 6b End view of Section 1 of switchgear showing extent of damage

Fig 6c Rear view of Grid 1, Bulldale Street and adjacent panels

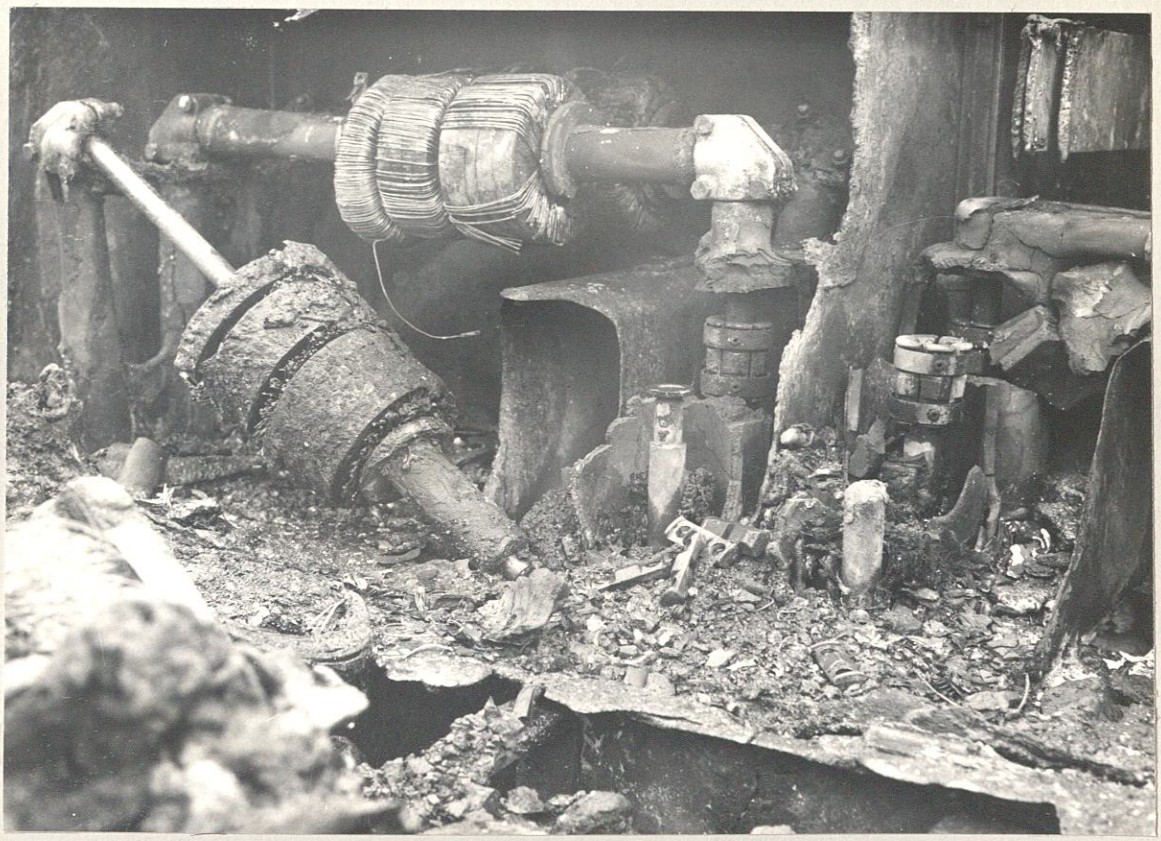


Fig 6d Bus bar and C.T. chamber of Clydeholm Terrace feeder adjacent to Grid 1

Fig 6e Moving contact assembly removed from bottom of circuit breaker tank

Fig 6f Circuit breaker tank

YOKER FERRY ROAD SUBSTATION
BULLDALE STREET FEEDER CIRCUIT BREAKER

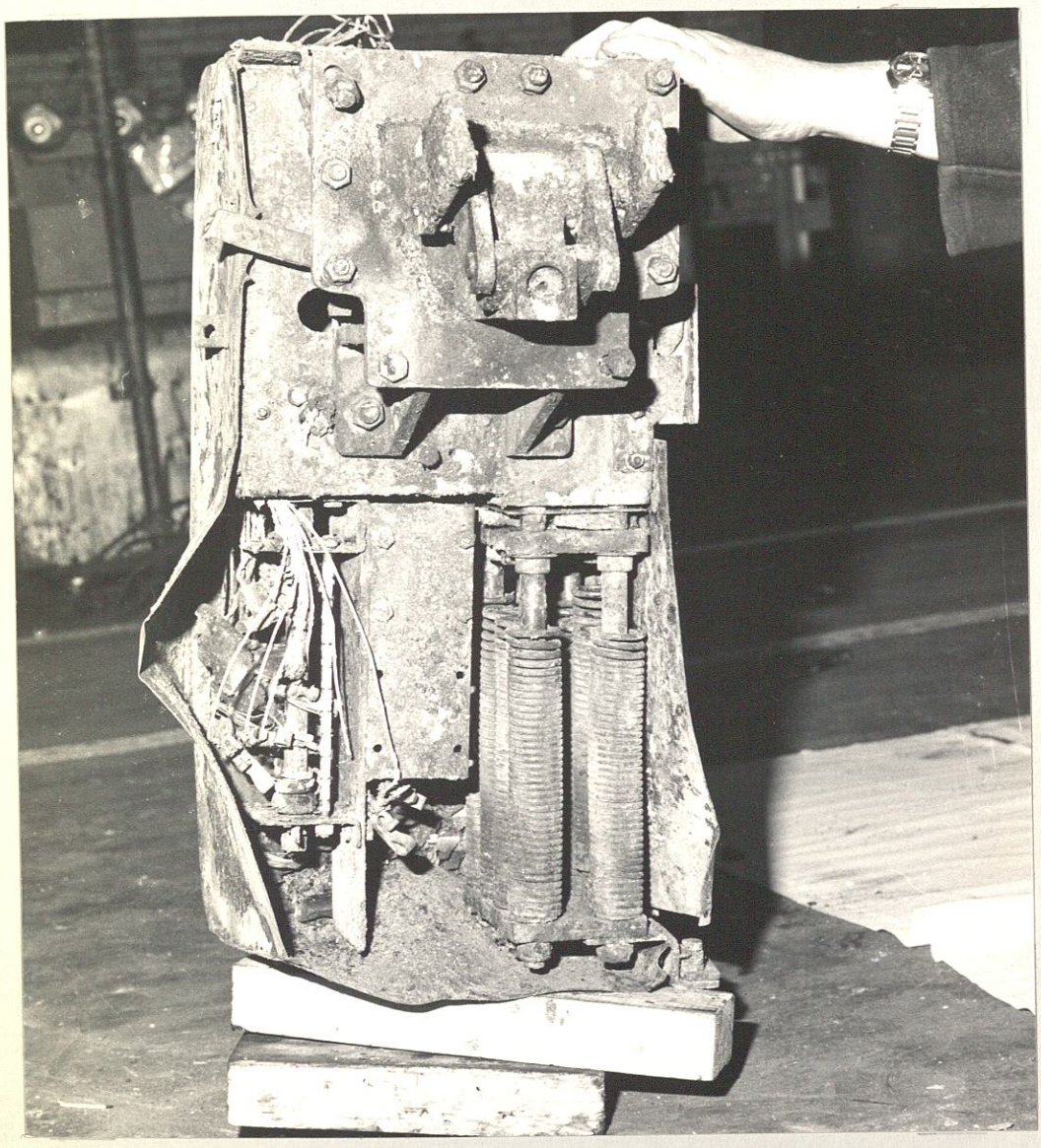


Fig 6g Circuit breaker operating mechanism

YOKER GRID SUBSTATION
MAIN D.C. BATTERY FUSES

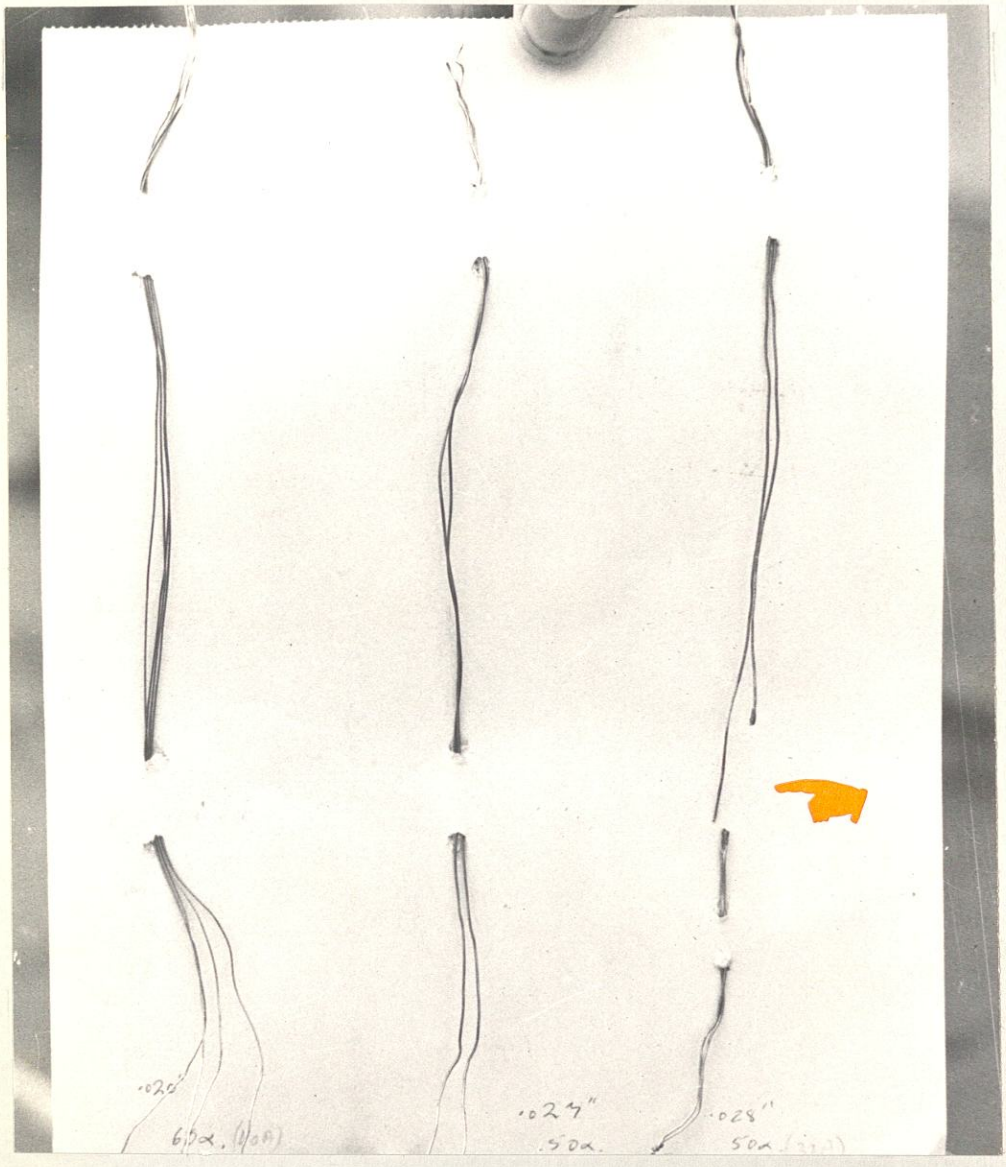


Fig 7 Elements after removal from fuse holders showing open circuit element on right hand side.

PRELIMINARY SUPERGRID AND GRID FAULT REPORT APPENDIX 1a

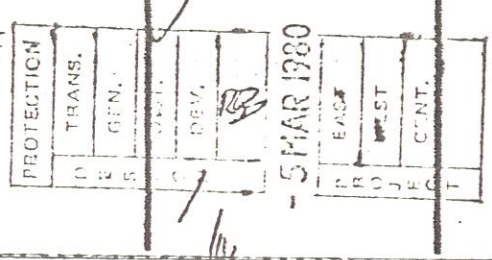
1	Fault Number	55 1979 | 80 GRID 154 (a)			
2	Day, Date and Time	TUESDAY 4th MARCH 1980 AT 16.49			
3	Location of Fault	YOKER GRID 1			
4	Operation of Protection and Circuit Breakers:				
	Station	Circuit Breaker	Panel	Protection	Relay
	YOKER	GRID 1		PROTECTION [illegible] DIST. E/F CENT. [illegible] RB 5 MAR 80 PROJECT [illegible] E/F CENT.	
5	Cause of Fault	AREA BUS BAR FAULT			
6	Injuries	NONE REPORTED.			
7	Damage *	TO BE INVESTIGATED. - GRID 1 DESTROYED.			
8	Load Interrupted and Duration	-			
9	Circuit Operating Conditions (Before Fault)	NORMAL.			
10	Remarks: Action Taken - including Restoration of Supplies and Alterations to Load Dispatching.				
	SWINGER TRANSFORMER T3 FAILED TO LOAD 11kV BUS SECTION SWITCH BS1 FAILED TO TRIP.				
7*	CONT GRID 1 & No 1 SECTION OF 11kV BUS BARS DESTROYED.				
11	Final Fault Report to be issued by:- SYSTEM OPERATION				

Section	Person Informed	Time	
Distribution	HEARN.		Signed: R. L. [illegible]
Telecommunications			Grid Control Engineer
Protection			
Transmission	SWANSON MELROSE		
Generation			Date: 4 3 80 Time: 1615

PRELIMINARY SUPERGRID AND GRID FAULT REPORT — APPENDIX 1b

1	Fault Number	SS 1979/80 GRID 155 (b)
2	Day, Date and Time	TUESDAY 4TH MARCH 1980 AT 1650 hrs.
3	Location of Fault	WINDYHILL - PARTICK - YOKER No 2 cct.
4	Operation of Protection and Circuit Breakers	

Station	Circuit Breaker	Panel	Protection	Relay
WINDYHILL	705	PARTICK / YOKER No 2.	O/C TRIP RELAY	FLD
			YELLOW ϕ O/C	PBO
			I/K SEMP	DAN 3
PARTICK	GRID 2.	H.V. PANEL	I/K REC	DBM
		L.V. PANEL	HIGH SPEED TRIP RELAY	[illegible]
YOKER	—	NONE		



5	Cause of Fault	AREA BUS BAR FAULT AT YOKER
6	Injuries	NONE REPORTED. AT YOKER
7	Damage	TO BE INVESTIGATED: TRANSFORMER T2 JANNED?
8	Load Interrupted and Duration	~30 MW AT YOKER. *
9	Circuit Operating Conditions (Before Fault)	YOKER - GRID 1 OPEN, TRANSFORMER T3 (SWINGER) HV ISOLATORS OPEN.
10	Remarks: Action Taken - including Restoration of Supplies and Alterations to Load Dispatching	

YOKER TRANSFORMER T2 FEEDING AREA BUSBAR FAULT, EVENTUALLY CLEARED BY WINDYHILL 705 ON OVER-CURRENT; YOKER HV ISOLATED AT 1724 hrs.
YOKER GRID 3, GRID 2 OPENED ON MECHANICAL TRIP AT 1800 hrs.

* 2115 hrs. 25% LOAD RESTORED VIA L.V. NETWORK.

11 Final Fault Report to be issued by:- SYSTEM OPERATION

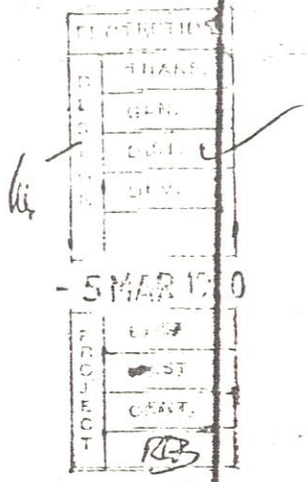
Section	Person Informed	Time	
Distribution	MILLAR		Signed: [signature] Grid Control Engineer
Telecommunications			
Protection			
Transmission	SHARKSON MORROW		
Generation			Date: 4.3.80 Time: 10.30

PRELIMINARY SUPERGRID AND GRID FAULT REPORT APPENDIX 1c

1	Fault Number	SS 1979/80 GRID 156 (C)
2	Day, Date and Time	TUESDAY 4TH MARCH 1980 AT 1659 hrs.
3	Location of Fault	WINDYHILL - PARTICK - YOKER No1 cct.

4 Operation of Protection and Circuit Breakers

Station	Circuit Breaker	Panel	Protection	Relay
WINDYHILL	305	} OPENED	MANUALLY.	
PARTICK	GRID 1			



5	Cause of Fault	ARER CONTROL REQUEST. YOKER DEMP - FIRE
6	Injuries	NONE REPORTED.
7	Damage	-
8	Load Interrupted and Duration	PARTICK LOAD = 35 MW FOR 29 min.
9	Circuit Operating Conditions (Before Fault)	WINDYHILL - PARTICK - YOKER No 2 on FAULT - YOKER GRID 1 OPEN BUS BAR FAULT.
10	Remarks: Action Taken - including Restoration of Supplies and Alterations to Load Dispatching	

FOLLOWING ISOLATION OF H.V. FEEDERS AT YOKER.
WINDYHILL - PARTICK No1 WAS A.T.S. AT 1728 hrs.
" " No2 " " " 1732 hrs.

11 Final Fault Report to be issued by:- SYSTEM OPERATION

Section	Person Informed	Time
Distribution	MILLAR.	
Telecommunications	SMITH	
Protection		
Transmission	SWANSON MELROSE	
Generation		

Signed: ..... Grid Control Engineer

Date: 4-3-80 Time: 19.20

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 2 - EXTRACT OF SWITCHING LOG SHEETS 1368 AND 1369 OF GLASGOW/CLYDE AREA DISTRIBUTION CONTROL CENTRE - DATE 4 MARCH 1980

Location	Instruction/Report	Time Completed	Time Reported
D.C.C.	Yoker Distribution General Alarm received		
North District E.R.C.	No supply complaints received from Lesmuir St. & Kirkton Ave.		14.38
Blawarthill Hospital	Substation visited. No indications		14.50
11 Lesmuir Place	S/S visited. Indicator vandalised. 10 Bulldale St. oil switch opened		15.15
10 Bulldale St.	S/S visited. No indications but faint smell of burning.	15.26	15.28
Yoker Ferry Road	10 Bulldale St. OCB open on E/F, System E/F and neutral check operated - Reset		15.40
Blawarthill Hospital	Open 11 Lesmuir Place 11 kV O.C.B.	14.55	15.01
125 Kirkton Ave.	Close 20 Cairntoul Drive 11 kV oil switch (normally open point)	16.10	
10 Bulldale St.	Open Yoker Ferry Road 11 kV O.C.B.	16.15	
Yoker Ferry Road	Close 10 Bulldale St. O.C.B. - O.K. Re-open	16.25	
10 Bulldale St.	Open local transformer and 11 Lesmuir Place 11 kV O.C.B's	16.30	
10 Bulldale St.	Close Yoker Ferry Road 11 kV O.C.B.	16.35	
Yoker Ferry Road	Close 10 Bulldale St. 11 kV O.C.B. - Tripped immediately	16.35	
10 Bulldale St.	Open 1465 South St. Yarrows 11 kV O.C.B.	16.36	
10 Bulldale St.	Close local transformer and 11 Lesmuir Place O.C.B's	16.38	
Yoker Ferry Road	Close 10 Bulldale St. 11 kV O.C.B. - O/C relay destroyed and an explosion and fire occurred at substation	16.40	
D.C.C.	On Yoker Ferry Road panel the following indications were received:-	16.45	
Yoker Ferry Road	Grid 1 11 kV O.C.B. in D.B.I. (Don't Believe It) T1 Protection Trip Supply Faulty T1 Buchholz Gas T2 Protection Trip Supply Faulty T2/		16.45

Location	Instruction/Report	Time Completed	Time Reported
	T2 Buchholz Gas		
	Windyhill/Partick No. 1 Intertrip System Faulty		
	Windyhill/Partick No. 2 Intertrip System Faulty		
	Grid 1 Trip Supply Faulty		
	Grid 2 Trip Supply Faulty		
	Grid 3 Trip Supply Faulty		
	Transmission General Alarm		
	Distribution General Alarm		
	Telecommunications General Alarm		
	T3 Protection Trip Supply Faulty		
D.C.C.	Following request by District Engineering Section and with Grid consent an unsuccessful attempt was made to open Grid 1 and Grid 2 O.C.B's at Yoker Ferry Road (supervisory out of commission) At this time reports had been received of a major fire at Yoker Ferry Road S/S.	16.55	
Windyhill	Yoker/Partick No. 1 and No. 2 132 kV O.C.B's opened	16.59	17.00
Yoker Ferry Road	132 kV Isolators 113 and 213 opened locally		
Partick	Grid 1 and Grid 2 opened from Windyhill	16.59	
Windyhill	Yoker/Partick No. 1 132 kV O.C.B. closed	17.28	
Partick	Grid 1 33 kV O.C.B. closed	17.28	
Windyhill	Yoker/Partick No. 2 132 kV O.C.B. closed	17.32	
Partick	Grid 2 33 kV O.C.B. closed	17.32	
	Continuation on Wednesday 5 March 1980		
Blawarthill Hospital	Open 11 kV top and bottom links on 11 Lesmuir Place feeder	02.00	
11 Lesmuir Place	Open Blawarthill Hospital 11 kV oil switch and close earth switch	02.10	
Blawarthill Hospital	Apply portable earths on 11 Lesmuir Place feeder	02.28	
Blawarthill Hospital	Remove portable earths on 11 Lesmuir Place feeder		
11 Lesmuir Place	Open earth switch on Blawarthill Hospital feeder	14.45	15.10
Blawarthill Hospital	Close 11 Lesmuir Place top and bottom links and 11 kV O.C.B.	14.50	
11 Lesmuir Place	Close Blawarthill Hospital 11 kV oil switch	15.00	
	Note: While testing cable conditions ex 10 Bulldale St. S/S, it was found that the section 10 Bulldale St. to 1465 South St. Yarrows had an open circuit fault.		

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 3 - EXTRACT OF SWITCHING LOG OF WINDYHILL TRANSMISSION SUBSTATION CONTROL ROOM - DATE 4 MARCH 1980

Location	Instruction/Report	Time Completed	Time Reported
Windyhill	Yoker/Partick No. 2 132 kV O.C.B. 705 auto-tripped	16.53	
Partick	Grid 2 33 kV O.C.B. auto-tripped	16.53	
Windyhill	Yoker/Partick No. 1 132 kV O.C.B. 305 opened	16.59	
Partick	Grid 1 33 kV O.C.B. opened	16.59	
Windyhill	Yoker/Partick No. 1 132 kV O.C.B. 305 closed	17.25	
Partick	Grid 1 33 kV O.C.B. closed	17.25	
Windyhill	Yoker/Partick No. 2 132 kV O.C.B. 705 closed	17.31	
Partick	Grid 2 33 kV O.C.B. closed	17.31	
Windyhill	Kilbowie high speed ammeter cleared	17.45	
	Continuation on Wednesday 5 March 1980		
Windyhill	Yoker/Partick No. 1 132 kV O.C.B. 305 opened	02.09	
Partick	Grid 1 33 kV O.C.B. opened	02.09	
Windyhill	Yoker/Partick No. 1 132 kV O.C.B. 305 closed	02.45	
Partick	Grid 1 33 kV OCB closed	02.45	

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 4 - EXTRACT OF SWITCHING LOG OF GRID CONTROL CENTRE, STRATHKELVIN HOUSE - DATE 4 MARCH 1980

Location	Instruction/Report	Time Completed	Time Reported
From D.C.C. Hawick St.	Report - Grid 1 at Yoker tripped		
Strathkelvin	T2 Buchholz gas Indication - Grid 1 at Yoker	16.49	
Strathkelvin	D.B.I. (Don't Believe It) Indication - 705 at Windyhill and Grid 2 at Partick auto-trip	16.49	
To D.C.C.	Instruction - Open Grid 2, Grid 3 and Isolator 213	16.50	
	- Unable to comply - No supervisory?	16.50	
From D.C.C.	Report - Police request to make Yoker "dead"		16.57
To Windyhill	Instruction - Open 305 at Windyhill and Grid 1 at Partick	16.57	
To D.C.C.	Report - Yoker now "dead"	16.57	16.59
From D.C.C.	Request for restoration of supplies at Partick from West George Street		
N.S.H.E.B.	Report - Sloy-Killin circuit had tripped	17.09	
To Yoker S/S	Instruction - Open isolators 113 and 213 and lock off, also switch out auto-transfer scheme	17.14	17.24
To Windyhill	Instruction - Close circuit breaker 305 at Windyhill and Grid 1 at Partick	17.25	17.28
To Windyhill	Instruction - Close circuit breaker 705 at Windyhill and Grid 2 at Partick	17.30	17.32
To Yoker S/S	Instruction - Open Grid 1, Grid 2 and Grid 3 O.C.B's	17.53	18.00
To Yoker S/S	N.B. - Grid 1 would not open Instruction - Open isolator 313	19.43	19.44
To Yoker S/S	Instruction - Trip test Grid 3	19.45	
To Yoker S/S	Instruction - Isolate and lock off Grid 2 and Grid 3	20.04	20.32
Yoker S/S	Instruction - Close isolator 313	21.04	
	Pressure tests of Sections 2 and 3 of 11 kV busbars	21.15	
	Continuation on Wednesday 5 March 1980		
To Yoker S/S /			

Location	Instruction/Report	Time Completed	Time Reported
To Yoker S/S	Instruction - Put isolators 118 and 218 out of commission and lock off	01.44	01.55
To Yoker S/S	Instruction - Close and trip Grid 3	01.57	01.59
To Windyhill	Instruction - Open 305 at Windyhill and Grid 1 at Partick	02.10	02.12
To Yoker S/S	Instruction - Close isolator 118 and commission on remote	02.15	02.20
To Windyhill	Instruction - Close 305 at Windyhill and Grid 1 at Partick	02.45	02.45
To Yoker S/S	Instruction - Close Grid 3	02.54	02.54
To D.C.C.	Instruction - Open and close Grid 3 at Yoker	03.06	03.08
To Yoker S/S	Instruction - Commission isolator 218 for remote control operation	03.10	03.40
To D.C.C.	Instruction - Open Grid 3 at Yoker	04.57	05.00
To D.C.C.	Instruction - Close Grid 3 at Yoker	05.02	05.03

REPORT OF THE BOARD OF INQUIRY INTO THE LOSS OF SUPPLY
AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 5 - PROTECTION OPERATIONS

All protection relays dependent upon an a.c. input from current transformers and/or the 50V d.c. battery supply to initiate tripping, alarm or indication signals operated correctly as indicated below, but due to the lack of the 110V d.c. battery supply, no circuit breaker tripping took place.

All protection relays dependent upon the 110V d.c. battery supply to initiate tripping alarm or indication signals failed to operate.

(a) Distribution

Time	Yoker Ferry Rd. Circuit	Protection Operations
14.38	Bulldale St. OCB tripped	IDMT Relay - Earth fault element
16.30	Bulldale St. OCB tripped	IDMT Relay - Earth fault element
16.45	Bulldale St. OCB closed but did not trip	IDMT Relay - R and B overcurrent & Earth Fault elements
16.45+	Busbar Protection Zone 1	R,Y,B elements and neutral check relay
	Busbar Protection Zone 1	Trip supply fail relay
	Busbar Protection Zone 2	Trip supply fail relay
	Busbar Protection Zone 3	Trip supply fail relay

Time	Alarms and Indications Operations	
	Yoker Ferry Rd. S/S Annunciator	Dis. Control Centre Annunciator
14.38	Feeder auto-trip and system earth fault	Distribution general alarm
16.30	Feeder auto-trip and system earth fault	Distribution general alarm
16.45+	Not known	Distribution general alarm Transmission general alarm Telecommunications general alarm Grid 1 OCB - D.B.I. T1 Protection trip supply faulty T1 Buchholz gas T2 Protection trip supply faulty T2 Buchholz gas T3 Protection trip supply faulty Grid 1 Trip supply faulty Grid 2 Trip supply faulty Grid 3 Trip supply faulty Feeders - Trip supply faulty Windyhill/Partick No. 1 - Inter-trip system faulty Windyhill/Partick No. 2 - Inter-trip system faulty

Distribution/

Distribution System Cable Faults

Bulldale St. S/S - South St. Yarrows Feeder - 300m from Bulldale St.

Bulldale St. S/S - Lesmuir Place Feeder - immediately outside Bulldale St. S/S wall.

(b) Transmission

Location	Panel	Relay Flag Indications
Yoker Ferry Rd. 11 kV relay room	Grid 1 Grid 1 Grid 2 Grid 3	Instantaneous earth fault Intertrip circuit unhealthy Intertrip Intertrip circuit unhealthy
Yoker Ferry Rd. 132 kV relay room	T1 T1 T2 T2 Partick/Windyhill No. 1 Partick/Windyhill No. 2 132 kV alarms 132 kV alarms 132 kV alarms 132 kV alarms	IDMT overcurrent relay - R,Y,B elements Intertrip supply supervision Differential earth fault IDMT overcurrent relay - R,Y,B elements Trip supply fail Trip supply fail T1 Buchholz gas T2 Buchholz gas Battery charger fail Battery earth fault
Windyhill Control & 132 kV relay room	Partick/Yoker No. 2 Partick/Yoker No. 2 Partick/Yoker No. 2 Partick/Yoker No. 2 Alarms Alarms	IDMT overcurrent relay - Y element Intertrip send Trip relay Partick Alarm - Auto-trip General alarm transmission, Auto-trip High speed ammeter operated
Partick 132/33 kV Substation	Windyhill/Yoker No 1 HV Windyhill/Yoker No 2 HV Grid 1 L.V. Grid 2 L.V.	Intertrip receive Intertrip receive Tripping relay Tripping relay
Grid Control Strathkelvin House	Yoker Windyhill Partick	Grid 1 OCB - DBI (Don't Believe It) Circuit breaker 705 - Auto-trip Grid 2 OCB - Auto-trip

At Yoker Substation, the following protection relays require the 110V d.c. battery supply in addition to any other inputs to initiate tripping or alarm signals and as a result, no operations took place.

Grid/

Grid 11 kV IDMT Overcurrent Relays) Fitted with shunt connected
Grid 11 kV Standby Earth Fault Relay Stage 1) trip reinforcing flag indicator
Grid 11 kV Standby Earth Fault Relay Stage 2) relay in addition to direct tripping circuit.

Transformer Buchholz trip (Main Buchholz)) Initiates "Transformer Protection
Transformer winding temperature trip) Operated" alarm at the Distribution
Auxiliary transformer Buchholz trip) Control Centre.

Reactor Buchholz trip) Initiates "Reactor Protection Operated"
Reactor winding temperature trip) alarm at the Distribution Control Centre.

Relay Operating Time Calculations

Substation	Circuit	Fault Current	C.T. Ratio	IDMT Overcurrent Relays		
				Plug Setting	Time Setting	Op. Time
Yoker Ferry Rd. 11 kV	Bulldale St.	11,180A	400/1	125%	0.6	1.32 sec
Yoker Ferry Rd. 11 kV	Grid 1	5,590A	2000/1	125%	0.25	2.15 sec
Yoker Ferry Rd. 11 kV	Grid 2	5,590A	2000/1	125%	0.25	2.15 sec
Yoker 132 kV	Grid T1	466A	150/0.5	150%	0.27	2.7 sec
Yoker 132 kV	Grid T2	466A	150/0.5	150%	0.27	2.7 sec
Windyhill 132 kV	Yoker/Partick 1	466A	500/1	150%	0.4	In-operative
Windyhill 132 kV	Yoker/Partick 2	466A	500/1	150%	0.4	In-operative

At Windyhill, the overcurrent relays on the two Yoker/Partick circuits are required to be given a plug setting equivalent to not less than 130% of the total MVA capacity of the circuit.

Total Transformer Rating of each circuit = 30+30+60MVA
= 120 MVA
Cyclic rating of 130% of Full Load = 156 MVA

Plug setting of 150% on the overcurrent relay =

$$\frac{1.732 \times 132 \times 500 \times 1.5}{1000} = 171 \text{ MVA}$$

Plug setting of 125% on the overcurrent relay =

$$\frac{1.732 \times 132 \times 500 \times 1.25}{1000} = 143 \text{ MVA}$$

Therefore a plug setting of 150% is the minimum for the Yoker/Partick overcurrent relays, but even with a setting of 125% there was insufficient fault current to cause operation of the overcurrent relays at Windyhill, as the fault current was equivalent to only 106.5 MVA.

With/

With a plug setting of 150%, the overcurrent relays at Windyhill will reach about 66% into the high voltage windings of the transformers at Yoker.

This explains why the No. 1 circuit was not cleared by the overcurrent relay at Windyhill, but the No. 2 circuit was tripped out by its overcurrent relay due to the consequential fault in the windings of transformer No. 2 at Yoker Grid substation.

SOUTH OF SCOTLAND ELECTRICITY BOARD

REPORT OF PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 6 - SUMMARY OF STATEMENTS MADE BY MR. T. CRAIG AND MR. D. CAMERON OF GLASGOW NORTH DISTRICT ENGINEERING DEPARTMENT

(Engineer in Charge:- Mr. T. Craig)

In response to a Distribution General Alarm from Yoker Ferry Road primary substation notified to District by the Distribution Control Centre, T. Craig and D. Cameron proceeded to Blawarthill Hospital substation, having ascertained from "no supply" complaints being received that the section from Yoker Ferry Road to Kirkton Avenue via Bulldale Street and Blawarthill Hospital was dead. Both engineers travelled in the same car.

At Blawarthill Hospital, the substation was found to be dead and all circuit breakers closed, there being no flag indications on any protection relays.

It was deduced that the fault was back towards Yoker Ferry Road and the S.16 unit at Lesmuir Place was checked and found to be dead with all switches closed, there being no fault passage indication because the indicator was vandalised. With the agreement of the Control Engineer, (G. McAllister), the Bulldale Street oil switch of the S.16 unit at Lesmuir Place was opened and locked off.

The next check at Bulldale Street ascertained that the substation was dead, with all circuit breakers closed, (except the normally open Yoker Garage feeder). A slight smell of burning was noted but nothing found on inspection.

NOTE: Yoker Ferry Road and Lesmuir Place circuit breakers are non-automatic.

At Yoker Ferry Road, the Bulldale Street feeder was found open on inverse definite minimum time earth fault, with system earth and check relays operated, the annunciator indicating "Auto-trip" and "11 kV Feeder Fault". All alarms and indications were then cancelled.

By agreement with Control, the Lesmuir Place circuit breaker at Blawarthill Hospital was opened, and the 20 Cairntoul Drive switch at Kirkton Avenue was then closed restoring supplies to Blawarthill Hospital and part of Anniesland Shopping Centre.

The engineers returned to Bulldale Street and carried out a close examination of the substation opening all cubicle doors and checking all cable boxes, trenches, current transformers and switchgear. Top cubicles were examined by flashlamp through the expanded metal doors. The L.V. board and the air circuit breaker were also examined.

It was agreed with the Control Engineer to open the Yoker Ferry Road circuit breaker at Bulldale Street and energise the Bulldale Street feeder from Yoker Ferry Road. This was done successfully and it was then agreed to energise each section in turn out of Bulldale Street; the Bulldale Street circuit breaker at Yoker Ferry Road was then opened to facilitate dead switching at Bulldale Street.

At/

At Bulldale Street, the Local Transformer and Lesmuir Place circuit breakers were opened leaving South Street Yarrows circuit breaker closed. The Yoker Ferry Road circuit breaker was also closed. At this stage the engineer examined the local transformer and cable connections and found all in order.

At Yoker Ferry Road with the agreement of the Control Engineer, the Bulldale Street circuit breaker was closed but opened immediately on I.D.M.T. earth fault; there was a co-incident slight dip in the lights. All indications and alarms were then reset.

It was agreed with the Control Engineer that the fault was probably on the Bulldale Street to South Street Yarrows section and switching was agreed to open the Yarrow South Street circuit breaker at Bulldale Street and close the Local Transformer and Lesmuir Place circuit breakers. This switching was completed and a further examination of the switchboard at Bulldale Street showed no signs of distress.

At Yoker Ferry Road, the Bulldale Street circuit breaker was closed and the lights in the control room went out immediately, there was a "growling, groaning" noise and one of the engineers who had been looking towards the Bulldale Street control panel was aware of sparking and flashing in the control room. Coincidently there were sounds of explosion outside.

The engineers vacated the control room, which was in darkness, and from the slabbed area outside heard a roaring noise from Bulldale Street and saw billows of brown smoke and flames. After a very short delay, (approx. 1 second) there was the sound of an explosion from the centre of number 1 busbar section at Yoker Ferry Road which expanded into arcing and a "huge explosion".

Convinced that the whole board was going up, the engineers attempted to escape via the back gate at the reactor building but in opening the padlock, which was jammed, their only master key broke.

At the main gate, one of the engineers, (T. Craig), climbed the fence and contacted a police squad car in the vicinity of the ferry, requesting them to contact the Distribution Control Centre via police control asking for the Grid incomers at Yoker Ferry Road to be tripped immediately. An ex-directory number to the Control Engineer was given. T. Craig also asked one of the policeman to keep the crowd back which had gathered in the vicinity of the switchboard.

By this time the other engineer had got out of the compound and an attempt was made to reach the radio in his car but could not pass the switchgear because of the intense heat. After trying to 'phone from two locations at the ferry, a member of the public volunteered the use of telephone and T. Craig spoke to the Control Engineer, G. McAllister, and said, "Get the supply off the Grid Transformers". The Control Engineer said, "Just a minute" and after a pause of approximately 20 seconds said "That's it done". T. Craig estimated that from the onset of the fault to disconnection was approximately 15 minutes.

At this stage the engineers were extremely concerned for the safety of the public and along with the police, kept them clear. By the time that the energy was disconnected, other police cars had arrived and the police were in control.

The Fire Service arrived and were advised not to use water, foam only was used.

SIGNED..... Mr. T. Craig

SIGNED..... Mr. D. Cameron

SOUTH OF SCOTLAND ELECTRICITY BOARD

REPORT OF PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11kV SUBSTATION ON 4 MARCH 1980

APPENDIX 6(a) - ADDITIONAL STATEMENTS BY MR. T. CRAIG AND MR. D. CAMERON

Shortly after the switchboard was de-energised, J. Boyle on secondment to Baillieston Protection Section, arrived on site and was investigating the d.c. emergency lighting at Yoker Ferry Road. He commented that the battery and the wiring were very hot. Emergency lighting was not available.

Whilst T. Craig was in the control room talking to a police officer, he suggested that they step outside to allow the police officer to take notes because the control room was still in darkness.

Whilst outside, J. Boyle came from behind them and said (to nobody in particular), that he was going down to the Grid compound to investigate what would be required to enable the right hand side of the board to be energised.

A little while later, Tom Craig, (and R. Perks of Glasgow North District, D.Cameron and the police officer), noticed smoke and/or steam coming from the voltage transformer on the right hand side of the board. There was no noise coming from the voltage transformer, nor was there a lot of smoke, more of a drift up round the sides.

J. Boyle was walking back towards the board by this time and Tom Craig asked him, "Surely that board is not energised again?"

J. Boyle did not answer but ran back to the Grid compound. A few minutes later, the smoke stopped.

T. Craig now back in still darkened control room when R. Melrose appeared with another person, (cannot remember who). T. Craig asked him, "Did you energise that half of the Board again?. R. Melrose replied, "No", walked round the control room and after a while, went outside.

Approximately 15 mins. later, D. Swanson, Windyhill, appeared and did some switching on the 11 kV board.

SIGNED Thos. W. Craig ..... Mr. T. Craig

SIGNED D. Cameron ..... Mr. D. Cameron

SOUTH OF SCOTLAND ELECTRICITY BOARD

REPORT OF PANEL OF ENQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 7 - SUMMARY OF THE STATEMENTS MADE BY MR. W. MILLER AND MR. G. McALLISTER, CONTROL ENGINEERS AT THE GLASGOW/CLYDE AREA DISTRIBUTION CONTROL CENTRE

Mr. W. Miller was the Senior Control Engineer (Acting) on Tuesday, 4 March 1980.

Note:- To the point at which the switching sequence was agreed between Mr. T. Craig (of Glasgow North District), and Mr. G. McAllister, to energise the Local Transformer and Lesmuir Place Feeders at Bulldale Street from Yoker Ferry Road, the control room logs and statements by Mr. G. McAllister agree completely with the statements by Mr. T. Craig and Mr. D. Cameron (see Appendix 6).

At 16.45 hrs. while waiting confirmation of the agreed switching programme, a number of indications were received on the Yoker EHV system diagram annunciator including Grid 1 D.B.I. (Don't Believe It). (See Fault Log, Appendix 2).

A telecommunications fitter was working on the adjacent panel and Mr. G.McAllister ascertained that the alarms were not spurious. Mr. McAllister them attempted to call Yoker Ferry Road by telephone and radio, (the telephone rang out with no reply). Mr. W. Miller contacted Mr. A. Johnston, switching engineer at Grid Control, and informed him of Grid 1 D.B.I. and that they would be informed when all other alarms were noted.

At this stage the Emergency Reporting Centre informed the Control Room that there was a fire in the Yoker direction. Mr. Miller asked Mr. J. Graham, the head clerk, to inform the fire brigade. (Mr. Graham subsequently reported that the fire service were already aware of the fire.)

Mr. Miller then received a call from Police Control, Pitt Street, relaying a message from an engineer asking for Yoker substation to be made dead. Mr. Miller contacted Grid Control who instructed him to open 132 kV Isolator 213 at Yoker (No. 2 line from Windyhill).

Note:- Log entry for 16.55 was stated by Mr. Miller to be erroneous and should read "Unsuccessful attempt was made to open Isolator 213 (supy. O.O.C.)".

Following failure to open Isolator 213, Mr. A. Johnston, Grid Control, was contacted and requested to make Yoker Ferry Road bars completely dead from Windyhill.

At 16.59, Mr. Johnston informed the Distribution Control Centre that No. 1 and No. 2 circuits were open at Windyhill. The Distribution Control Centre was subsequently informed that Windyhill-Yoker/Partick No. 2 circuit had tripped out at 16.57 hrs.

The/

The possibility of recovering Partick on 33 kV interconnection was considered and Glasgow North District was 'phoned to get engineers to Partick and West George Street to assess loads and possible degree of recovery. Mr. D. Morton of Glasgow North District was contacted by radio and asked to go to Partick.

Grid Control advised that Isolators 113 and 213 were open at Yoker and that they were ready to close Grid 1 and Grid 2 at Partick. They asked whether any interconnection had been established to Partick on the 33 kV system.

Mr. McAllister received a call from Police Inspector Hunter that the board had been made live again and asking for reassurance that it was dead. Following this call, Mr. Miller queried the position of the Grid T3 swinger transformer with Grid Control and was informed that the swinger had been switched out by Mr. D. Swanson prior to opening the No. 1 circuit at Windyhill. Mr. Miller relayed information to the police that the board was "clear".

At the same time, Mr. McAllister called Mr. Morton by radio and asked him to investigate at Yoker Ferry Road. Mr. Morton subsequently confirmed that the board was dead.

Police Inspector Hunter timed his call at between 17.30 and 17.45 hrs. and Mr. Morton timed the radio call from Mr. McAllister at 17.36 hrs.

Signed ..... Mr. W. Miller

Signed ..... Mr. G. McAllister

SOUTH OF SCOTLAND ELECTRICITY BOARD

REPORT OF PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 8 - REPORT BY MR. R.T.F. MELROSE OF THE WINDYHILL TRANSMISSION GROUP

I was in the Windyhill Group Office on Tuesday, 4 March 1980. About 16.45 hours I observed a large column of smoke in the city in the Partick/Yoker area.

Some 5 minutes later, Mr. A. Johnstone, Grid Control Engineer, rang to state that Yoker Grid 1 was "D.B.I.", (Don't Believe It), at Grid Control and Glasgow Distribution Control Centre reported it OPEN. Grid T2 Main Buchholz Gas alarm was also up at the D.C.C.

I reached the front door of the Group Office intending to go to Yoker when my attention was attracted by the noise of an arc and I saw a flash and smoke in Windyhill 132 kV substation in the area of the gantry above OCBs. 305 and 705. A few seconds later I heard an OCB open. I dashed back to the office and asked Donald Swanson to look at these happenings in the Windyhill 132 kV control room, then I made my way by car towards Yoker.

While on the way, I received a radio-telephone call from Grid Control informing me that they had had a request from the Police/Fire dept. to make Yoker dead and were doing so. I acknowledged this and enquired if Partick was being back fed. The reply from Grid Control cannot be recalled. During the journey, Grid Control confirmed that Yoker was dead.

On arrival at Yoker, I entered via the lower (Ferry) gate, opened by a Mr. Proudfoot, noting that there was a fire at the 11 kV substation. Fire engines were in the road, the firemen having used the small gate let into the fence to the rear of the 11 kV switchboard. I drove up to the 11 kV compound, the gate there being already open and was approached by a fireman who required to know whether the switchboard was dead. I replied that it was from the Grid viewpoint. I called the Distribution Control Centre via the radio-telephone to confirm that the board was also dead from the 11 kV side and to ask if District engineers were on site. The Control Centre replied yes to both questions. The fireman overhead the conversation and went off in the direction of the switchboard.

I then went to the Grid site to confirm the state there, opening up the 132 kV control rooms to do so. I telephoned Grid Control (Mr. A. Johnston) to ask if he required isolation at Yoker and whether Partick was off supply. He confirmed yes and I requested whether I should isolate T1 and T2 at Yoker and was instructed by Johnston to open isolators 113 and 213. This operation was undertaken by hand, having tried unsuccessfully to open the isolators electrically at the LOCAL position. Fortunately, two engineers from the Telecommunications Section, (Mr. M. Boddie and Mr. D. Brower), arrived at this time and they assisted me in opening isolators 113 and 213 using an operating handle from a switching isolator, the correct handle having been vandalised. It was also noted at this point that the explosion vent of Transformer T2 had ruptured and a considerable quantity of oil was evident on the chippings and inside the oil retaining wall. Both switching isolators were also OPEN.

Having/

Having confirmed that both 113 and 213 were open, I removed the fuse and links and Castell keys. Back in the 132 kV control room I reported the switching by telephone and switched off the auto-switching scheme on the instructions of Grid Control. I also reported the fact that the number one half of the 11 kV switchboard was on fire and the fact that T2 showed evidence of an internal explosion. I then enquired if Partick was being switched back in and was told yes.

During the course of my conversation with Grid Control, Mr. J. Boyle entered the control room. Mr. Boyle asked whether he could be of any assistance and on being told that he could not at that time, left the control room. I remained there until Grid Control confirmed that Partick had been re-energised. This took place some three or four minutes after the departure of Mr. Boyle.

I left for the 11 kV compound and was approached on arrival by a Senior Fireman, (in a white hat), who had apparently been told that the switchboard had been re-energised. I pointed out that only the 132 kV overhead lines into the Grid compound were live and that the 11 kV switchboard had not been made live by the Grid. Mr. Boyle was not involved in these discussions, in fact no Board personnel were identified at this time although there were SSEB personnel present.

At this point, John Mitchell, the Windyhill Group Engineer and Donald Swanson arrived at the 11 kV site, being met by myself. Donald and I took relay flag indications in the 11 kV control room with the aid of a torch. We then went back to the 132 kV control room and took the indications there. The main battery fuse-links, (re-wireable), were examined at this time, confirming one of the fuse-links was blown, (which one was not noted). The battery room was not entered. Donald Swanson repaired the fuse-links with 8 strands of 15 amp fuse wire, the wire from the battery fuse-links being removed and put on one side for future examination. Prior to replacing the links, all d.c. switches with the exception of the emergency lighting were turned to the OFF position, The main battery fuse-links were then replaced and switches returned to the ON position.

At this time, the fire had been out for some time and the firemen had departed. I returned to the 11 kV control room. Area and Glasgow North District staff were active in assessing the position under the charge of Mr. David Dalgleish. I asked Mr. Dalgleish his intentions and confirmed that it was the intention to inspect and test the remaining part of the 11 kV switchboard with a view to re-energising in due course.

From the Grid viewpoint it was obvious that T3 was the only transformer available to feed Yoker and work was undertaken to this end.

I spoke to Mr. A. Winter, Area protection engineer, and assisted in splitting the d.c. closing ring and the control/relay panel ring. Donald Swanson was undertaking trip testing and I also assisted in this work.

In reply to a question by Mr. R.B. Howie, I confirmed that no Grid protection engineer was on site at this time although Mr. Mitchell had telephoned for such assistance on arrival at Yoker.

(Donald Swanson had previously opened 11 kv circuit breakers Grid 2 and Grid 3 on instructions from Grid Control prior to the replacement of the battery fuse-links in the 132 kV compound).

I proceeded to assist in the restoration of the supply, T3 being restored to the Windyhill-Partick-Yoker No. 1 line. The transformed was re-energised by closing circuit breaker 305 at Windyhill.

I left Yoker at approximately 04.00 hours on Wednesday, 5 March 1980.

Signed: R.T.F. Melrose R.T.F. MELROSE

SOUTH OF SCOTLAND ELECTRICITY BOARD

REPORT OF PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 9 - SUMMARY OF STATEMENT MADE BY MR. D. SWANSON OF THE WINDYHILL TRANSMISSION GROUP

At about 16.50 hrs. on 4 March 1980, Mr. D. Swanson had just reached the top of the stairs to his office when he met Mr. R. Melrose on his way out. Mr. Melrose told him that he had had a telephone call from Grid Control to the effect that Grid 1 at Yoker had tripped, or had gone D.B.I. ("Don't Believe It" indication) at Grid Control. Mr. Melrose then left but returned almost immediately to tell Mr. Swanson, who by now was in his office, that he thought he had seen a flash and heard circuit breaker 705 at Windyhill trip out. (This controls the number 2 circuit to Partick and Yoker Grid substations). Mr. Swanson said he would go to the 132 kV control room at Windyhill, Mr. Melrose going to Yoker as planned.

In the 132 kV control room, Mr. Swanson found that circuit breaker 705 had tripped on yellow phase overcurrent inverse definite minimum time protection and noted all the alarms and indications, which were correct for the fault trip condition. Grid Control then telephoned to the 132 kV control room and told Mr. Swanson that there was a fire at Yoker and would he switch out the No. 1 circuit. He said that the quickest way was to open circuit breaker 305, (controlling number 1 circuit to Partick and Yoker), and was told to do so and the attendant at Windyhill then opened circuit breaker 305, the time being about 17.00 hrs. No isolators were opened at Windyhill. Alarms were received from Partick relating to the pilot supervision circuits and intertripping circuits due to the loss of supplies at Partick.

Mr. Swanson then informed Grid Control that he was going to Partick to check the alarms there as Mr. Melrose was on his way to Yoker. On his way to Partick he overheard radio-telephone conversations between Mr. Melrose and Grid Control and then, changing channels, between Mr. Melrose and the Distribution Control Centre. He informed Mr. Melrose what had been done at Windyhill and that he would contact him again from Partick Grid substation. Arriving at Partick around 17.15 hrs. he found the substation completely dead with no L.V. supplies. The automatic emergency lights were lit in the 33 kV relay room and he checked the relay indications which were identical for Grid 1 and Grid 2, "Intertrip Receive", "HV/LV Trip Relay", "Auto-trip" plus "Voltage Control Faulty" and "Pilot Fail" due to loss of the L.V. supply. There was nothing inconsistent with the system conditions. Mr. D. Morton of Glasgow North District then arrived and asked what had happened. Mr. Swanson told him that there was a fire at Yoker and that Mr. Melrose was there. Mr. Swanson then telephoned Grid Control to pass on the information regarding the alarms and indications at Partick and was asked to wait at Partick as it was intended to re-energise that substation. After resetting all alarms, Partick was re-energised at about 17.30 hrs. by closing circuit breakers 305 and 705 at Windyhill and Grid 1 and Grid 2 at Partick, all from Windyhill. He noted the voltmeters on the tap change control panels reading, first one, then the other, probably Grid 1 first as that is the usual sequence of switching. He checked the tap changers for similarity of tap positions and made sure the L.V. supplies were normal and then left to go to Yoker.

Arriving/

Arriving at Yoker around 17.45 hrs., he parked his car in Bulldale Street and walked round to the Grid substation. He noted presence of police and fire services and saw that the 11 kV switchboard was covered in foam. There was no sign of fire and no detectable heat as he walked to the main gate. He found Mr. J. Mitchell of the Windyhill Transmission Group and Mr. Melrose in the 132 kV control room, the lights of which were out. Mr. Melrose was discussing with Grid Control via the telephone what he was to do. Mr. Swanson was in the 132 kV relay room when Grid Control called via the red telephone and asked him whether Grid 2 and Grid 3 11 kV circuit breakers were closed or open. He said he did not know but would go and look. Control said, "Do, and if closed, open them". He mentioned this to Mr. Mitchell and Mr. Melrose and then went to the 11 kV switchboard and found Grid 2 and Grid 3 both closed. Failing to trip them electrically, he tripped them using the manual push button and then reported his actions to Grid Control from the 11 kV control room at around 18.02 hrs.

Mr. Melrose came into the 11 kV control room and they decided to check the relays, alarms and indications in there. This was done by using a torch as the control room was in darkness. The burnt relay on the 10 Bulldale Street panel was also noted. After a discussion about the fault and possible causes they both returned to the 132 kV control room. It was noted that the d.c. lights were off. The fact that no tripping had taken place and that the 132 kV isolators 113 and 213 had to be opened manually, i.e. no d.c. supply to them, indicated that there was a major failure of the d.c. supply. Mr. Swanson, Mr. Melrose and Mr. Mitchell then went and checked the main battery fuses on the wall in the 132 kV relay room and found one of them had blown. It was noted that the main fuses must have been underrated to have blown before any other fuses. All three fuses were rewired, and before replacing them, all busbar feeds were switched off. The main fuses were then replaced and the d.c. lights switched on first. All the other circuits were then switched on, one at a time. A battery earth fault alarm came on when the supply to the 132 kV relay panel was closed and this was eventually traced to the auto-switching panel on wires associated with Grid 1 and was reckoned to be on the passing contact or auxiliary switches circuit on that circuit breaker. The links to the switching isolators were removed as well as the links and fuses on the auto-switching relay panel. Four wires to the auto-switching circuit which were earthy* were then disconnected, clearing the battery earth alarm. The relay panel links and fuses were replaced but still left out of the switching isolator circuits. After this time Mr. Melrose was involved in issuing the necessary isolating requests to the District staff.

During the course of the night, Mr. Swanson and Mr. Melrose did a complete trip test on T3. It was noted also when testing T3, that a particular relay did not appear to operate. Having failed to contact Mr. B. Martin of the Protection Project Sub-Group (Central) at his home, Mr. Swanson returned to Windyhill, via Kilbowie to note the high speed ammeter, to obtain the necessary drawings. Examination of the drawings showed that the relay in question was a flag repeat relay only. Mr. Swanson said that he was not aware of seeing any member of the Protection Section at Yoker.

In the early hours of Wednesday morning, 5 March, the Partick/Yoker No. 1 circuit was switched out at Partick and Windyhill and isolators 313 and 118 at Yoker were made ready, and after replacing the links and fuses, they were closed. All personnel at Yoker were then warned to stay clear and at 03.30 hrs. circuit breaker 305 at Windyhill was closed, energising Grid T3 at Yoker. Mr. Swanson and Mr. Mitchell noted that on restoration of supply, the charger indicated a battery charge of around 43 amps. which persisted for a time before decaying slowly. They then had a look around the transformer in the compound and seeing nothing amiss went to the 11 kV control room where Mr. Melrose had closed Grid 3 11 kv/

* as a direct result of the fire

11 kV circuit breaker and re-energised the 11 kV switchboard. Mr. Swanson then returned to Windyhill office around 04.00 hrs., Mr. Melrose having gone to Partick at 04.00 hrs to reset alarms.

Signed Donald N. L. Swanson (Mr. D. Swanson)

SOUTH OF SCOTLAND ELECTRICITY BOARD

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 10 - REPORT BY MR. J. BOYLE, ENGINEER ON SECONDMENT TO THE PROTECTION SECTION PROJECT SUB-GROUP AT BAILLIESTON

Travelling home from West George Street substation on Tuesday, 4 March 1980, I noticed smoke rising from the west of the city.

By the time I had reached Ferry Road, Yoker, the smoke had largely subsided. I explained to the police at Ferry Road that I worked for the Board and, having parked my car in Dumbarton Road, proceeded on foot to the Yoker Ferry Road 132/11 kV substation site, entering via the main entrance.

I had noted a "burnt" smell on passing the 11 kV substation site but no radiant heat. Firemen were still hosing down the 11 kV board using foam. I entered the 11 kV control room and found two Glasgow North District engineers working by the light of a torch and asked, following identification, whether I could be of any assistance. It was stated that there was trouble on the Bulldale Street circuit and that the circuit breaker had not cleared the last closure, but it was obvious that the engineers lacked all the facts at the time.

I had a feel around the 110 volt battery distribution board situated in the 50 volt telecommunications battery room and thought the surface of the board to be warm, casually remarking on this fact to the other engineers.

Proceeding down to the 132 kV relay room, I found Robin Melrose there and asked whether any assistance was required. Robin stated that it was fairly well in hand and that they were getting ready to restore 132 kV into Partick.

Since no assistance was necessary at the 132 kV compound, I proceeded back to the 11 kV substation and on arriving there, concern was expressed to meby the Glasgow North District engineers about the smoke and steam which had appeared, to my recollection, to the right hand side of No. 1 section of the switchboard. The amount of smoke etc. did not seem great to me but, in view of the concern of the District engineers, I proceeded briskly back to the 132 kV relay room and reported the facts to Robin Melrose prior to returning again to the 11 kV compound.

I was met by the Fire Chief who asked, "Is it safe? is the board alive?" At this point, Robin Melrose arrived from the 132 kV site and I referred the Fire Chief to Robin and to another engineer from the District. Discussion took place between the Fire Chief, his assistant and the two SSEB engineers; I did not take part in this discussion.

John Mitchell arrived at this time in the 11 kV compound and queried what had happened. I referred him to Robin who was still busy with the Fire Chief just around the corner of the substation building.

I do not recall the fire brigade directing any water or foam to the substation at this time, they appeared to be tidying up. I left the substation a few minutes later, having told John Mitchell and Robin Melrose of this intention; they may not, however, have heard this comment.

Signed: Joseph Boyle MR. J. BOYLE

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 11 - SWITCHGEAR DAMAGE REPORT

1 SUMMARY

This report describes the switchgear equipment involved and details the damage which resulted at both the Bulldale Street and Yoker Ferry Road substations during the incident on 4 March 1980.

Possible reasons for the loss of the 110V d.c. supply being attributed to the disturbances at Yoker Ferry Road substation are also examined.

2 BULLDALE STREET SUBSTATION

2.1 Switchgear Details

The switchboard in Bulldale Street substation consists of a five panel wall-mounted 11 kV bulk-oil circuit breaker arrangement of cellular construction manufactured by Ferguson Pailin Ltd. The circuit breakers are of 400A current rating type BRP3 having manually charged spring-operating mechanisms (type XE) and a short-circuit rating of 250 MVA at 11 kV to BS 116 : 1952. The circuit breakers are located in the switchboard with fixed individual phase, manually dependent, operated isolators situated above and below each circuit breaker. The isolators are each contained in their own compartment, the front of which is formed by a mesh hinged door. The cables are connected directly via cast cable boxes to the bottom terminals of the lower isolators, whilst the top isolators are connected directly via porcelain through bushings mounted in the top of each busbar isolator compartment, to the busbars. The busbars are air-insulated, of copper rod construction and are mounted on porcelain stand-off insulators which are, in turn, mounted on top of the busbar isolator compartments. The busbar compartment is open to the front of the switchboard and there is no phase or unit segregation along the length of the busbar run. Segregation between circuit breaker compartments, isolator compartments and the busbar compartment is, however, achieved by concrete barriers. The switchboard was commissioned in 1932 as Bulls Metal substation and has been modified over the years to the present form as described above. Two of the circuit breakers, the incomer from Yoker Ferry Road and the Lesmuir Place feeder are non-automatic and are used only as oil-immersed isolators. Wall mounted 415V open-type switchgear is mounted on the wall of the switchroom opposite to that supporting the 11 kV switchgear.

2.2 Fault Details

The arcing products from a cable fault subsequently found to have occurred on the Lesmuir Place feeder just outside the substation found their way back along the unblocked cable ducting to cause a three-phase to earth fault at the cable termination and isolator compartment of this feeder. This fault subsequently caused a three-phase busbar fault to occur.

2.3/

2.3 Examination of the Switchgear Subsequent to the Incident

The isolators and associated connections in the cable compartment of the faulted feeder circuit were completely burned away, the cast cable box lying in the bottom of this compartment. The busbars were also largely burned away at the seat of the busbar fault and all the supporting insulators were broken. An outer phase busbar isolator of the faulted feeder circuit had suffered severe burning and the isolator moving contact blade was found to be in a partially open position. The equipment had suffered from the effects of severe burning in the areas associated with the fault. All circuit breakers appeared, nevertheless, to be intact with tanks, bushings etc. in position.

The incoming circuit breaker opened freely when tripped by its associated push button. Subsequent detailed examination confirmed that all the circuit breakers were still capable of mechanical operation and except for the South Street Yarrows feeder were relatively clean, internal examination showing the fixed and moving contacts, arc-control devices, oil and tank interiors to be in a clean condition. The South Street Yarrows circuit breaker had at some time operated to clear a three-phase fault, the oil being heavily carbonised and the fixed and moving contacts on all poles were moderately burnt. However, this circuit breaker had not operated to clear the cable fault subsequently located on the feeder some 300m from the substation, since a protection fault had not allowed the circuit breaker to be tripped.

The substation building was found to be structurally undamaged apart from the windows which had blown out. The products of arcing and the heating associated with the faulted 11 kV switchgear had caused the 415V switchgear situated on the opposite wall of the substation to be damaged beyond repair.

3 YOKER FERRY ROAD SUBSTATION

3.1 Switchgear Details

The 27 panel 11 kV switchboard at Yoker Ferry Road substation is of the outdoor, metalclad vertically isolated, integrally earthed type manufactured by South Wales Switchgear Ltd. The busbars are 2000A rating and are split into three sections by two 2000A bus section circuit breakers. Section 1 (the left hand side of the switchboard), consists of twelve 400A feeder circuits with a centrally located 2000A incoming circuit breaker "Grid Transformer 1". Similarly, Section 2, (the right hand side of the switchboard), consists of twelve feeder circuits all of which are 400A rating except the extreme end circuit, "Renfrew Ferry No. 2" which is of 800A rating. A 2000A incoming circuit breaker, "Grid Transformer No. 2" is centrally located in Section 2; busbar segregation is provided at each of the bus section units. Between the two bus section circuit breakers, i.e. Section 3, is located a 2000A incoming circuit breaker, "Grid Transformer No. 3". All 2000A circuit breakers are solenoid closed, as are the two feeder circuit breakers "Weirs Pumps" and "Renfrew Ferry No. 2". The remaining circuit breakers are fitted with hand-charged spring-closed type SC7 mechanisms equipped with remote electrical release. The 2000A circuit breakers are type DOX, the 800A circuit breaker is type C8X and the 400A circuit breakers are type C4X.

This switchgear has a short-circuit rating of 250 MVA at 11 kV to BS 116: 1952 and a rated impulse voltage level of 75 kV. All primary connections are fully enclosed in PVC and/or epoxy insulation and are contained in air-filled metalclad/

metalclad chambers, thus complying with the requirements of the SSEB Switchgear Specification S.2.0. No busbar barriers are employed between units since these components reduce the impulse level of the switchgear. The circuit breaker controlling the Bulldale Street feeder is situated within Section 1 of the switchboard and is physically adjacent to the left hand side of Grid Transformer No. 1 circuit breaker.

3.2 Fault Details

The faults within the Bulldale Street substation were fed via the Bulldale Street circuit breaker on the Yoker Ferry Road switchboard. Since this circuit breaker finally failed to trip, the associated fault continued to be fed. The three-phase fault current has been estimated to be approximately 11 kA.

The 11 kV switchgear at Yoker Ferry Road substation is designed to carry without damage currents of up to 13.1 kA for 3 secs. in accordance with Electricity Supply Industry and British National Specifications. Currents of this magnitude flowing for durations much in excess of 3 secs. would cause damage to the switchgear due initially to gross overheating, (melting), and ultimately to arcing where contact is lost. With a fault current of some 11 kA, the equipment could be expected to remain intact for some 5 secs. However it is evident from the engineers at the substation that the switchgear did in fact survive for some 10 secs. or more prior to major damage occurring since it was not until the engineers were outside the relay/control room that they observed problems occurring at Section 1 of the switchboard. The disruption continued to be fed until final clearance occurred as a result of the 132 kV circuit breaker 305 at Windyhill was opened some 14 mins. later.

It is to be fully expected that a current of 11 kA passing for some tens of seconds will eventually cause thermal failure of the switchgear. Such a failure will obviously occur at a point in the equipment design having the highest heat generation and associated lowest thermal capacity. The region satisfying this requirement is that occurring at the isolating contacts between the fixed portion of the switchgear and the removable circuit breaker.

3.3 Examination of the Switchgear Subsequent to the Incident

Examination of the remains confirms that the circuit side isolating contact areas of the Bulldale Street feeder were the primary seat of the failure at the switchgear. The contact systems and the top plate of this unit had completely disappeared and molten metal had fallen into the circuit breaker tank and solidified. The circuit breaker moving contact system together with its fixed contacts still intact and in full and correct engagement with the moving contacts, i.e. in the fully closed position, were found at the bottom of the circuit breaker tank, held in place by solidified deposits of aluminium. Detailed examination of the contact systems of this circuit breaker confirmed that any arc erosion was fully consistent with that to be expected when operating under the fault conditions to which it had been subjected during the events prior to the main incident. The feeder side bushing stems had been burnt completely away to the top of their fixed contact assemblies, whilst some 80-120mm had been burned from the busbar side bushing stems. The tank was intact and showed no signs of burning or distortion. The burning associated with the top plate area had caused a hole to be burned in the rear mild steel sheet cubicle. This burning had eroded through the cable box and had also involved the cable box of the adjacent unit, i.e./

i.e. Grid Transformer No. 1, causing this to be completely burned away. The top plate of Grid Transformer No. 1 circuit breaker was intact as were the top plates of all the other circuit breakers involved in the burning associated with the fault.

As a direct result of the above incident at the circuit side of the Bulldale Street feeder, the busbars of the equipment were also faulted, allowing the No. 2 side of the switchboard to feed some 5-6 kA into the region. The disposition of the fault infeed to the busbars was such that it caused the resultant arcing to run along the entire length of the No. 1 Section busbar, (due to magnetic forces). This was evident from the examination of the remains of the equipment; apparent "cut-off" had occurred at the Clydeholm Terrace feeder, (adjacent to the right hand side of Grid Transformer No. 1 panel), whilst the seven panels to left of this feeder were completely burned away to the level of the circuit breaker top plates. This damage involved both busbars and circuit chambers. Temperatures of several thousands of degrees Kelvin would have occurred during the process described above, such temperatures being more than sufficient to melt and to vaporise any of the materials in the path of the fault arcs.

An examination of the mechanisms of the circuit breakers in the burned-out region of the switchboard confirmed that all were in the CLOSED position except that associated with the Marathon Tee No. 3 feeder which was in the OFF position.

The closing mechanism of the Bulldale Street feeder circuit breaker was removed and carefully examined; this was also found to be in the fully latched position with the trip latch still behind the trip roller, i.e. the circuit breaker had not received any signal to trip.

4 POSSIBLE REASONS FOR THE LOSS OF D.C. SUPPLIES

Apart from the reasons ultimately considered applicable, (see Appendix 13), the loss of the 110V d.c. supply was also considered from the following switchgear viewpoints:-

4.1 The possibility of the power fault associating itself with the d.c. control wiring has been examined. In this respect, the relay on the Bulldale Street circuit breaker at Yoker Ferry Road was found to have operated correctly, the operating time being 1.32 sec. as described in Appendix 5. From the evidence of the two Glasgow North District engineers, (Appendix 6), some tens of seconds must have elapsed from the time the circuit breaker was closed to the time when the Yoker Ferry Road switchboard erupted. Had association of the fault current with the switchboard d.c. conductors been the cause of the loss of the d.c. supply, it would have been necessary for the fault current to have burned through at least two mild steel plates, which would have delayed the necessary damage to the d.c. system by several tens of seconds.

4.2 A further possibility considered was that the fault had caused a rise in earth potential sufficient to induce flash-over between the switchgear metal enclosure and the d.c. wiring which was at earth potential. However, even considering the worst possible case of the metal enclosure rising to line potential, i.e. 9 kV above earth, it is unlikely that the d.c. wiring PVC insulation, or the air-gaps associated with the wiring terminations, would have flashed over. Measurement of the earth resistance subsequent to the fault confirmed that the value was less than 0.01 ohm and the maximum voltage difference could not therefore have been greater than 100V.

In view of the above, both possibilities were discounted.

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 12 - REPORT ON TRANSFORMER TESTS

Tests were carried out on the windings and oil of Transformer No. 1 with the following results.

Transformer No. 1 :- Manufacturer: Parsons Peebles Power Transformers Ltd.
Rating: 30 MVA, Ratio: 132/11 kV, Serial No. 43162
Impedance: 20.3% Connection: YyO

Tap-Changer No. 1 :- Manufacturer: Hawker Siddeley Power Transformers Ltd.
Type: HS319/33/200 DNDRI, Serial No. 104634
Range: +10% to -20% in 18 steps of 1.67%.

Insulation Resistance Tests using 5 kV Megger

H.V. winding to Earth	:- 55 Mohms	(Including connections to transformer side of isolator)
L.V. winding to Earth	:- 850 Mohms	(Disconnected from earthing transformer)
H.V. winding to L.V. winding	:- 1100 Mohms	
Earthing Transformer to Earth	:- 1400 Mohms.	

Gas-in-Oil Analysis (Carried out on 5 March 1980)

	Main Tank	Tap-Changer Selector Tank
Gas content %	9.8	8.6
Hydrogen ppm	145	17.0
Methane ppm	40	3.8
Ethane ppm	5.9	1.4
Ethylene ppm	6.8	1.2
Acetylene ppm	3.8	4.3
Carbon Monoxide ppm	1630	101

Gas in Buchholz Relay

Hydrogen	0.33%
Methane	0.04%
Ethane	0.0%
Ethylene	0.0%
Acetylene	0.0%
Carbon Monoxide	1.75%
Carbon Dioxide	0.59%
Oxygen	7.5%
Nitrogen	Remainder

Voltage/

Voltage Ratio Tests

Supply:- 415 volt 3 phase to H.V. terminals A.B.C.

Tap Position	Volts on L.V. Terminals	
	a-c	b-c
1	13.25	13.25
2	13.04	13.05
3	12.84	12.84
4	12.63	12.64
5	12.43	12.43
6	12.22	12.22
7	12.02	12.02
8	11.82	11.81
9	11.61	11.61
10	11.41	11.41
11	11.25	11.24
12	11.04	11.04
13	10.84	10.85
14	10.64	10.64
15	10.44	10.44
16	10.23	10.23
17	10.03	10.03
18	9.82	9.82
19	9.62	9.62

Magnetising Current Tests

Supply:- 240 volts 1 phase to each pair of H.V. terminals in turn

Tap Position	Current in Milliamps		
	A-B	B-C	C-A
7	26	26	26

Resistance Test of L.V. Windings (Temperature below 10°C)

a-b:- 0.01936 ohms b-c:- 0.01940 ohms c-a:- 0.01936 ohms

REPORT OF THE PANEL OF INQUIRY INTO THE LOSS OF SUPPLY AT YOKER FERRY ROAD 132/11 kV SUBSTATION ON 4 MARCH 1980

APPENDIX 13 - REPORT ON THE 110V BATTERY, CHARGER AND D.C. SUPPLIES

Historical Review of Plant Changes

Yoker 132 kV substation was one of the original Central Electricity Board sites, being commissioned in 1929. It was equipped with four bulk-oil circuit breakers of MVE type, four circuit entries and three 15 MVA 132/11 kV transformers. The battery installed was of the open cell Planté design of 250Ah capacity, i.e. fully capable of supplying the 300A + coil current associated with the closing solenoids of the circuit breakers.

At a somewhat later stage, one circuit breaker was removed and the circuit entries reduced to two.

During 1948/49, the battery was replated and all components renewed with the exception of the glass containers themselves.

Since 1950, a number of layout alterations and plant changes have been made. In 1954 a fourth transformer was added. In 1956, the three bulk-oil circuit breakers were uprated from 1500 MVA to 2700 MVA, (a measure necessitating higher closing energy), whilst in 1962, two 15 MVA transformers were replaced by 30 MVA units.

A new relay room was also built in 1962, the battery referred to above being re-sited within the new accommodation. The original battery board with knife switches, mercury contactors etc, was eliminated in 1962 and replaced by the present arrangement, including the battery charger. It is probable that the dimensions of the fuse-links applied at this period have since been maintained.

In 1964, the solenoid-closed circuit breakers were replaced by pneumatically closed equipment of higher rupturing capacity, and in 1969, a new battery of 100 Ah capacity was installed in place of the original battery equipment.

Arrangement at Time of Incident

During the period 1972/75, the circuit breakers were removed, the substation being modified to the present layout, i.e. that of a duplicate transformer-feeder utilising a "swinger" transformer with associated switching isolators. The present 11 kV switchboard was also established at this time, replacing the 11 kV switchgear in the by now redundant Yoker generating station.

The battery, charger and d.c. distribution board is situated in the 132 kV relay room building and not only supplies the 132 kV substation equipment, but also the 11 kV switchgear and control equipment via multi-core cables, the distance between the two locations being approximately 180 metres.

The/

The d.c. supply arrangements at Yoker Grid substation are in accordance with the requirements of Transmission Plant Standard 9/3, (CEGB Standard 99391). Fig. 3 shows the arrangement of the 110V battery, charger and d.c. supplies to the 11 kV switchboard. The main battery fuses are connected between the battery and the d.c. busbars to which the charger and the outgoing d.c. supply circuits are connected. These main fuses, which are of the rewireable type, were wired such that the main + ve fuse and the 48 cell - ve tapping fuse were rated at 48A with a minimum fusing current of 70A, and the main 55 cell - ve fuse was rated at 60A with a minimum fusing current of 85A.

The outgoing circuits to the 11 kV switchboard closing supply and to the control supply are also rewireable and were wired to give a rating of 140A with a minimum fusing current of 250A.

At the 11 kV substation the incoming fuses on the closing circuit were 100A HRC cartridge fuses and the closing ring circuits were protected by 80A HRC cartridge fuses so arranged that the two ring fuses were effectively in parallel as the ring was run closed.

As regards the main battery fuses, a check back through the history of the battery reveals no record of when the fuses were wired as they were found after the incident, nor any justification for such a low rating.

There appears to have been a lack of liaison between the Transmission Construction Section carrying out the new work, and the Transmission Operation and Maintenance Section who were responsible for the equipment remaining operational at the time when the "swinger" transformer and the 11 kV switchboard were installed. This lack of liaison led to the lack of co-ordination of the fuses in the main battery and closing circuits.

Maintenance of the Battery

Maintenance and a thorough inspection of the battery is undertaken by a representative of the battery manufacturing company on a bi-annual basis, when individual cell voltages and electrolyte gravities are checked. The extent of wear, growth and distortion of the positive plates is recorded and performance during boost charge is noted.

A log of battery maintenance as such is not kept. The battery is inspected during the weekly routine substation inspection; individual cells are examined for acid level and the battery voltage and charge rate are recorded. Two samples of the weekly inspection sheet are attached, one covering an inspection carried out on Tuesday, 4 March 1980 prior to the incident, and one covering an inspection carried out on Tuesday 11 March 1980.

However, examination of the circuit diagram of the d.c. switchboard, Fig. 3, shows that the voltmeter would only record the true "battery only" voltage if the rectifier switch was moved to the OFF position. An open-circuit main battery fuse would then manifest itself by there being no reading on the voltmeter and by the operation of all the "trip supply healthy" alarm relays.

With the main battery fuses intact and the battery in its normal fully charged state floating across the d.c. busbars, no detectable current would be recorded by the main battery ammeter.

The/

The battery charger is supplied from the red phase of the 415/240V a.c. supply in the substation, which is normally derived from T3 earthing transformer. In the event of the loss of T3, the supply is automatically switched to T1 earthing transformer. The rating of the charger is 37A and the charger is rated at 17A. The normal standing load on the d.c. system is in the order of 1A, the battery being floated across the charger and taking a negligible current.

The battery charger alone would maintain the standing load and would be capable of operating a feeder circuit breaker spring-closing release coil, the current being around 4.5A. It would also be capable of operating a circuit breaker trip coil, provided that the a.c. input to the charger was healthy, the current being around 4.6A. As the charger rating is 17A, it is doubtful if, under these conditions, the charger could cope with a busbar tripping operation, as thirteen circuit breakers would require to be tripped simultaneously which would impose a demand of almost 60A on the charger The charger would certainly be incapable of supplying the closing coil current of 140A required by each of the solenoid-closed Grid and Bus Section circuit breakers.

As the last closing operation of a Grid circuit breaker took place on 28 February 1980, it is clear that the main battery fuses must have been intact at that time.

Operation of the Main Battery Fuses

It is considered that the discontinuity of the main battery fuse-element had not been caused as a result of a short-circuit fault current. Had the short-circuit current been large, the fuse-element would have volatilised; this had not happened. Had the short-circuit current been small, or had the fuse been subjected to an overload for a long period of time, complete burn-back of the fuse-element would have occurred; this had not happened. It is evident, therefore, that the fuse-element discontinuity had not been caused as a result of the fuse operating under either a high or a low fault current or a low long term overcurrent.

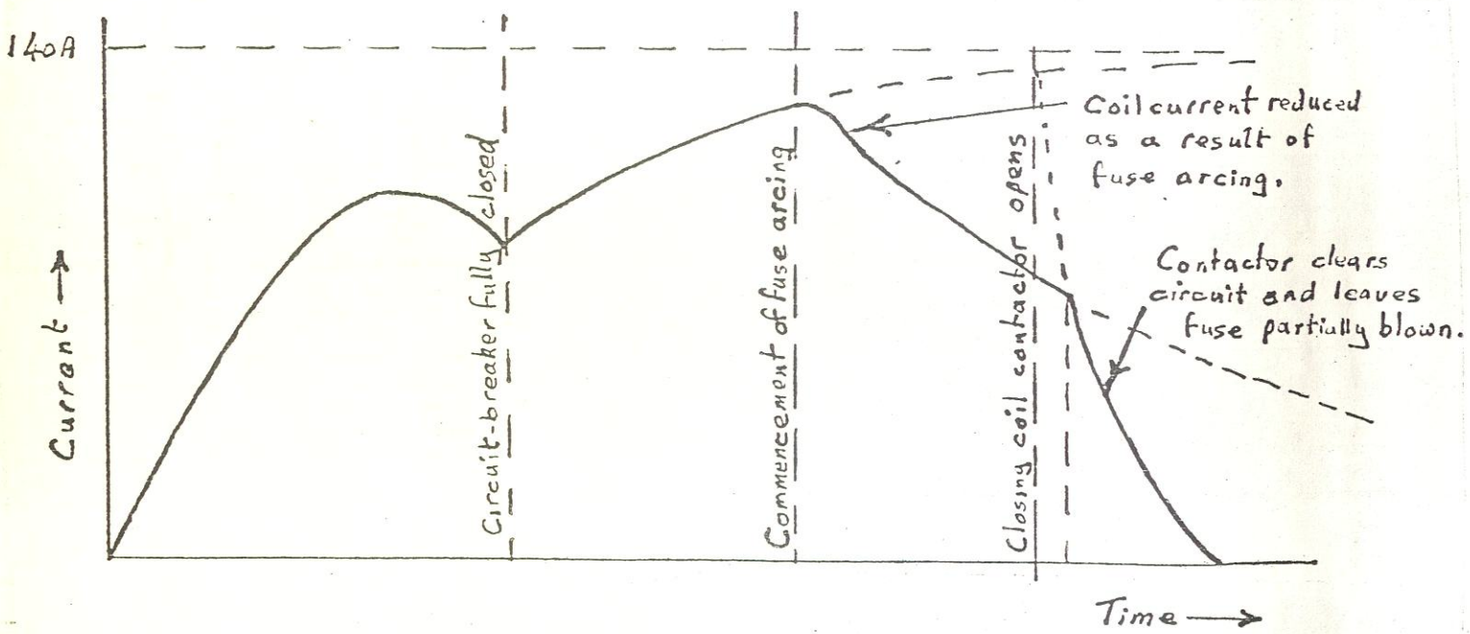
Examination of the faulted fuse-element shows that a small section of one of the two parallel fuse-elements had burned back for a very small distance, but the other element had only just parted. Oxidation of the element which had slight burn-back was more severe than the other one of the two parallel elements indicating that the former had taken a much larger share of the current than the latter. This is borne out by the fact that the latter element had not been fully clamped under the terminal screws.

Oxidation of a rewireable fuse is inevitable when carrying its rated current. This oxidation reduces the element cross-section, increases its resistance and thereby its temperature, the effect being cumulative until eventually, failure occurs. If the fuse consists of parallel elements, unequal current sharing of these elements will reduce the time to failure. The same effect will occur if the fuse is subjected to currents in excess of its rated current for short periods of time. The failure of this fuse is considered to be as a direct result of deterioration due to the current pulsing to which it had been subjected during circuit breaker solenoid-closing operations. Unequal current sharing of the two parallel elements would exacerbate the situation.

The/

The nominal closing coil current of the Grid and Bus Section circuit breakers at Yoker Ferry Road is 140A, the coil being energised for approximately 4 secs. Two 22 swg tinned copper wires in parallel, assuming equal current sharing, will blow in free air in 12 secs. However, at the other extreme, assuming current flow through one wire only, the blowing time will be some 2.5 secs. Current pulses of this magnitude and duration will cause deterioration of the fuse-element(s) at a rate dependent upon the frequency of circuit breaker closure. Such cumulative deterioration will manifest itself in the production of oxidation, reduced cross-sectional area of the elements and successively higher operating temperatures.

In the limit, the final closing operation is considered to have produced such a state at the fuse-elements that continuity was maintained only for a sufficient period of time to enable the circuit breaker to reach its fully closed position and latch, a discontinuity then occurring in the element(s) as a result of the continuing current flow and time duration prior to the coil current being switched off, (by the operation of the closing circuit contactor). See sketch below.



Post Incident Condition of Battery

After the main battery fuses had been rewired and replaced, on restoration of the 415/240V a.c. supply to the substation, the battery charge was around 43A for some time before decaying slowly, indicating that the battery was in a low state of charge. The last solenoid-closing operation had taken place five days before the incident, and no immediate recharging of the battery to make up for the 140A discharge for 4 secs. occurred due to the failure of the main battery + ve fuse at that time.

SOUTH OF SCOTLAND ELECTRICITY BOARD

YOKER SUBSTATION WEEKLY INSPECTION

DATE: 4/3/80

TEMP: 8 °C.

INSPECTED BY: W. Duffy

CHECKED BY:

SWITCHING ISOLATOR	118			218		
PHASE	R	Y	B	R	Y	B
INTERRUPTER HEAD SF6 PRESSURE INDICATOR	S	S	S	S	S	S
INTERRUPTER HEAD CONTACT INDICATOR	S	S	S	S	S	S
ACCUMULATOR PRESSURE psi	1800			1700		
ACCUMULATOR PRESSURE GAUGE SECTOR COLOUR	~~RED~~ GREEN			~~RED~~ GREEN		

ENTER S = SILVER R = RED Y = YELLOW
IF EITHER RED OR YELLOW APPEAR A GROUP ENGINEER MUST BE IMFORMED IMMEDIATELY BY PHONE.

	TRANSF. T1			TRANSF T3			TRANSF T2			R1	R3	R2
	R	Y	B	R	Y	B	R	Y	B			
MAIN BUSHINGS	1/2	1/2	1/2	1/2	1/2	1/2	1/3	1/3	1/3			
BREATHERS		B.			B			B		C	B	B
MAIN CONSERVATOR		1/3			1/3			1/3		1/3	1/3	1/3
DIVERTER SWITCH		1/2	B		1/2	B		1/2	B			
CURRENT TRANSFORMER		1/4			1/4							
EA. TRF. CONSERVATOR + BREATHER		1/3	B		1/2	B		3/4	B			
EA. RES. WATER LEVEL		2			1/2			N/I				
MAIN BUCHHOLZ		F			F			F			F	
EA. TRF. BUCHHOLZ	~~F~~	F	~~F~~	~~F~~	F		~~F~~	F	~~F~~	~~F~~	~~F~~	~~F~~
WINDING TEMP °C	No1 90	No2 27		No1 16	GAUGE No2 FAULTY		No1 39	No2 41		No1 30 30	No2 30	
T.C. COUNTER :-												
THIS WEEK	604			316			612					
LAST WEEK	584			290			586					
ADVANCE	20			26			26					

OIL

	GALLONS	BREATHER
CLEAN OIL	550	B
DIRTY OIL	425	

110V BATTERY

VOLTS	CHARGE RATE	ACID LEVEL
125	1 AMP	CORRECT

PHONE CHECK	G.P.O.	P.A.X.
	ok	ok

CAUTION IT IS EXPRESSLY FORBIDDEN TO LEAVE GROUND LEVEL TO TAKE ANY OF THESE READINGS

SOUTH OF SCOTLAND ELECTRICITY BOARD

YOKER SUBSTATION WEEKLY INSPECTION

DATE: 11/3/80

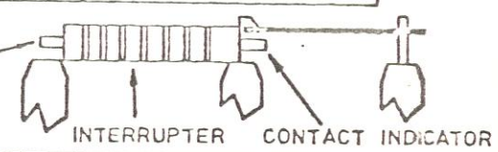
TEMP: 8 °C.

INSPECTED BY: W Duffy

CHECKED BY:

SWITCHING ISOLATOR	118			218		
PHASE	R	Y	B	R	Y	B
INTERRUPTER HEAD SF6 PRESSURE INDICATOR	S	S	S	S	S	S
INTERRUPTER HEAD CONTACT INDICATOR	S	S	S	S	S	S
ACCUMULATOR PRESSURE psi	1800			1700		
ACCUMULATOR PRESSURE GAUGE SECTOR COLOUR	~~RED~~ GREEN			~~RED~~ GREEN		

ENTER S = SILVER R = RED Y = YELLOW
IF EITHER RED OR YELLOW APPEAR A GROUP ENGINEER MUST BE IMFORMED IMMEDIATELY BY PHONE.



	TRANSF. T1			TRANSF T3			TRANSF T2			R1	R3	R2
	R	Y	B	R	Y	B	R	Y	B			
MAIN BUSHINGS	1/2	1/2	1/2	1/2	1/2	1/2	1/3	1/3	1/3			
BREATHERS		B			B			C		C	B	B
MAIN CONSERVATOR		E			1/2			1/3		1/4	1/3	1/4
DIVERTER SWITCH		1/2	B		2/3	B		1/2	No BREATHER			
CURRENT TRANSFORMER		W/L?			W/L?							
EA. TRF. CONSERVATOR + BREATHER		1/8	B		1/2	B		1/2	B			
EA. RES. WATER LEVEL		Z			1/2			W/L?				
MAIN BUCHHOLZ		F			F			W/L		F	F	F
EA. TRF. BUCHHOLZ		F			F			F				
WINDING TEMP °C	No1 Z	No2 Z		No1 36	No2 45 LUGG		No1 Z	No2 Z		No1 Z 32	No2 Z	
T.C. COUNTER:- THIS WEEK	634			373			615					
LAST WEEK												
ADVANCE												

OIL

	GALLONS	BREATHER
CLEAN OIL	540	B
DIRTY OIL	425	No BREATHER

110V BATTERY

VOLTS	CHARGE RATE	ACID LEVEL
125	0.8 AMPS	CHARGED

PHONE CHECK	G.P.O.	P.A.X.
	O/K	O/K

CAUTION IT IS EXPRESSLY FORBIDDEN TO LEAVE GROUND LEVEL TO TAKE ANY OF THESE READINGS